Failure Modes and Effects Analysis/Critical Items List For Fuel-Oxidizer Management Assembly and Combustion Chamber

Fluids and Combustion Facility Combustion Integrated Rack

Preliminary
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PREFACE

The National Aeronautics and Space Administration (NASA) is developing a modular, multi-user experimentation facility for conducting fluid physics and combustion science experiments in the microgravity environment of the International Space Station (ISS). This facility, called the Fluids and Combustion Facility (FCF), consists of three test platforms: the Fluids Integrated Rack (FIR), the Combustion Integrated Rack (CIR), and the Shared Accommodations Rack (SAR). This document is intended to produce a Failure Modes and Effects Analysis/Critical Items List for the Fuel-Oxidizer Management Assembly (FOMA) contained in the Combustion Integrated Rack (CIR).

FAILURE MODES AND EFFECTS ANALYSIS/CRITICAL ITEMS LIST FOR THE FLUIDS AND COMBUSTION FACILITY COMBUSTION INTEGRATED RACK FUEL OXIDIZER MANAGEMENT ASSEMBLY

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REVISION PAGE
FAILURE MODES AND EFFECTS ANALYSIS/CRITICAL ITEMS LIST

Revision	Date	Description of Change or ECO's/ECP's Incorporated	Verification and Date
Preliminary	10/25/00	Initial release for PDR	10/30/00

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1.0 INTRODUCTION

1.1 Purpose.

This document presents a preliminary Failure Modes and Effects Analysis (FMEA) and a Critical Items List (CIL) for the Fuel-Oxidizer Management Assembly (FOMA) of the Combustion Integrated Rack (CIR) which is part of the Fluids and Combustion Facility (FCF) that will be deployed on the International Space Station (ISS). This preliminary FMEA/CIL is intended to determine the possible functional failure modes and their effects on the FOMA and subsequently the CIR, the FCF, and the ISS. This analysis shall promote design improvements, and to promote early considerations of corrective actions in response to various failures. The CIL points to certain items/functions that thru specified failure modes could result in critical safety hazards or loss of capability to adequately perform the science experiments associated with the CIR.

1.2 Scope.

This preliminary analysis is restricted to the FOMA of the CIR and is not intended as an analysis of other CIR subsystems, FCF systems or space station vehicle hardware of any type. This FMEA/CIL is not intended to analyze the detailed “structure” or composition of 1. FCF software code, 2. software fault tolerance, 3. software design to initiate commands and control, 4. human error, 5. support structure and tubing, 6. electrical wiring, 7. electronic enclosures, 8. mechanical linkages such as power bolts, gears, and cranks.

1.3 Order of precedence for verification requirements.

The verification requirements contained in this document shall take precedence over any conflicting verification requirements.

2.0 DOCUMENTS

This section lists specifications, models, standards, guidelines, handbooks, and other special publications. These documents have been grouped into two categories: applicable documents and reference documents.

2.1 Order of precedence for documents.

In the event of a conflict between this document and other documents referenced herein, the requirements of this document shall apply. In the event of a conflict between this document and the contract, the contractual requirements shall take precedence over this document. All documents used, applicable or referenced, are to be the issues defined in the Configuration Management (CM) contract baseline. All document changes, issued after baseline establishment, shall be reviewed for impact on scope of work. If a change to an applicable document is determined to be effective, and contractually approved for implementation, the revision status will be updated in the CM contract baseline. The contract revision status of all applicable documents is available by accessing the CM database. Nothing in this document supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.2 Applicable documents

The documents in these paragraphs are applicable to the FCF Project to the extent specified herein.

SSP 30234	Failure Modes and Effects Analysis and Critical Items List Requirements for Space Station

2.3 Reference Documents

The documents in this paragraph are provided only as reference material for background information and are not imposed as requirements.

SSP 50431	Space Station Program Requirements for Payloads
SARGE	Standard Assurance Requirements and Guidelines for Experiments
CIR-PLAN-A-003	CIR Flight Safety Data Package
CIR-SDP-000	CIR Delta Phase 1 Safety Data Package
FCF-DOC-003	Combustion Integrated Rack Baseline System Description
Schematic	Combustion Integrated Rack – Fuel/Oxidizer Management Assembly

3.0 GENERAL APPROACH

After having established a mutual understanding of the functionality of the various major components of the system, CIR designers and reliability engineering have worked together to determine failure modes. Failure modes associated to a particular component/system have been described along with the component function, failure mode criticality, local failure effect, system effect, station/crew effect, potential failure mode cause, failure detection method, and compensating provisions. For PDR, the current concept for failure detection and compensating provisions was noted but is subject to change as our understanding of design and operations improves. Particular items of hardware and their associated failure modes have been selected as critical items and listed in the CIL for special attention. (Critical Items List- CIL) The CIL indicates specific failure modes associated with a specific device, component, or subsystem that could result in hazards or loss of capability to perform science experiments.

4.0 SYSTEM DESCRIPTION

The Fuel/Oxidizer Management Assembly (FOMA) provides the ability to safely deliver all gaseous fuels, diluents and oxidizers required to perform combustion experiments in the Combustion Integrated Rack (CIR) test chamber. The FOMA can also sample the test chamber environment via a Gas Chromatograph and control the venting of chamber gases, at acceptable concentration levels, to the International Space Station Vacuum Exhaust System (ISS VES).

The FOMA is comprised of two packages, the Gas Delivery Package (GDP) and the Exhaust Vent Package (EVP), which includes the Gas Chromatograph (GC). Each package is described in detail in the following sections.

The desired gases are supplied by the Experiment in 3 bottle sizes, which are 1.0 liter, 2.25 liter and 3.8 liter. These gases can be either pure or pre-mixed. The FOMA provides the interface for the bottles as well as ISS supplied nitrogen. The crew will be able to change out the bottles when required. The FOMA also controls the regulation of gas to the Combustion Chamber. On-orbit gas blending will be accomplished by two methods, partial pressure and dynamic mixing. Both of these methods can be used to pressurize the Combustion Chamber to the desired pressure and gas ratio. The dynamic mixing method can accommodate experiments requiring flow through.

The Exhaust Vent Package connects the Combustion Chamber with the ISS VES. The package includes the Experiment supplied adsorber cartridge and a re-circulation loop to convert post-combustion gases into species that are acceptable to vent. The adsorber cartridge may be required to remove water and filter particles. The GC will be used to verify the post-combustion gases meet ISS VES requirements prior to venting overboard.

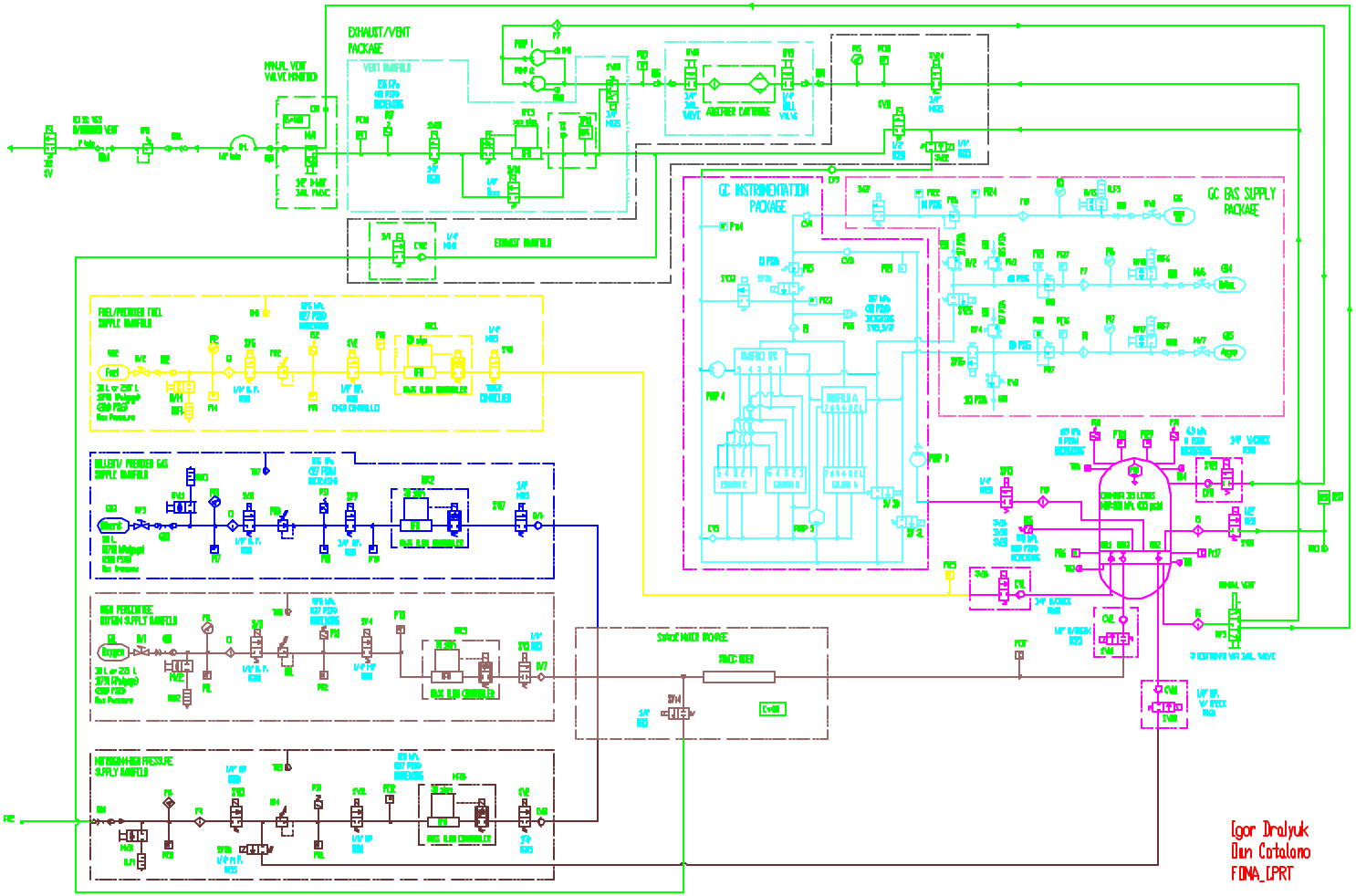

FIGURE 1. FOMA Schematic

4.1 FOMA DESIGN FEATURES/SPECIFICATIONS

FOMA Design Features:

- Capable of mixing 3 gases
- Utilizes ISS nitrogen
- Gases supplied by using up to three 3.8 L, 2.25 L, and /or 1.0 L bottles
- Bottle pressure up to 14Mpa (~ 2000 PSI)
- Static (Partial Pressure) blending
- Dynamic blending (mass flow controllers)
- High pressure supply directly from gas bottle
- Designed to clean: methane, propane, n-hepthane, CO, CO2, sulfur dioxide, nitrous oxide, H2O and others

FOMA specifications:

Gas Bottles Oxygen Composition:
1.0 L up to 85% O2 @ 14Mpa (2000PSIA)
2.25 L up to 50% O2@ 14Mpa (2000PSIA)
3.8 L up to 30% O2@ 14Mpa (2000PSIA)
Gas Blending Accuracy:
Partial Pressure Method: Less than ± 0.35% absolute
Dynamic Method:
Oxygen Blends: < 25%: ± 0.3% absolute
Oxygen Blends: > 25%: ± 2% of reading
Gas Flow Rates: +/- 1.0 Accuracy
Maximum from Each Supply (non-fuel): 30 SLM
Maximum Possible (All Supplies - non fuel): 90 SLM
Maximum Fuel: 2 SLM
Exhaust Vent Specifications:
Maximum Outlet Pressure = 275.8 kPa (40 psia)
Outlet Temperature = 16° - 45° C (60° - 117° F)
Maximum Dew Point = 16° C (60° F)
Combustion By-Products: Compatible with CIR and ISS VES
Concentration Limits:
Most Gases can be vented 100% by volume except the following:
All Fuels (gaseous state): 80% Lower Explosive Limit (LEL)
Oxygen: 30% maximum
Combustion By-products: 0.01% by volume

Adsorber Cartridge:

Sizes/Weights:
Maximum Diameter: 76 mm (3 inches)
Maximum Length: 355 mm (14 inches)
Weight (empty): 3.5 kg (8 lbs)
Adsorbing Material:
Lithium Hydroxide (LiOH)
BPL Activated Carbon
Silica Gel
Particulate Filters

5.0 FMEA/CIL GROUND RULES AND ASSUMPTIONS

1. The criticality categorization of a failure mode shall be made on the basis of the worst case potential failure effect regardless of probability of occurrence.

   [Derived from SSP 30234, "Instructions for Preparation of Failure Modes and Effects Analysis and Critical Items List for Space Station", Section 5.14.1]

2. When considering the failure modes for the internal failure of a component/system, all required functional ***inputs*** to the component/system (under analysis) shall be assumed to be present and correct.

   [Derived from SSP 30234, Section 5.11]

3. Maintenance procedures or availability of contingency or off-nominal crew (flight or ground) procedures shall not be considered as "unlike" redundancy or as a valid success path in determining the criticality of a component/system failure mode.

   [Derived from SSP 30234, Section 5.14.3]

4. The analysis shall identify ***all potential*** causes for Criticality 1 and 2 failure modes.

   [Derived from SSP 30234, Section 5.5]

5. Identical items which perform the same function(s)/capability(ies), in the same environment, (where the only difference is location) may be analyzed only once, provided that the failure effects for the items are the same.

   [Derived from SSP 30234, Section 5.12]

6. This preliminary FMEA shall be performed to the lowest functional level of analysis necessary to identify critical functions and items.

7. Blockage of orifices shall be considered a credible failure mode.

   [Derived from SSP 30234, Section 5.10.2]

8. The external leakage failure mode of any hardware item from any sources (except mating of two surfaces by inspectable welding, brazing, or permaswage) shall be considered a credible failure mode.

   [Derived from SSP 30234, Section 5.10.2]

9. Software code and details of human error in an operational scenario shall not be analyzed.

10. Containment vessels, such as combustion chambers and cylinders containing gases, shall be included in the FMEA.

11. Only credible failure modes will be analyzed.

6.0 CRITICALITY CATEGORIES

Categories of **1**, **1R**, **1S**, **1SR**, **2**, **2R**, or **3** shall be assigned to all failure modes of the FCF in order to classify all failure mode effects.

[Derived from SSP 30234, section 5.14.1]

1 – A single point failure that could result in loss (failure/damage) of flight hardware, of the ISS itself, or serious injury or loss of flight/ground personnel.

1R – Redundant items/systems, all of which failed, could result in loss (failure/damage) of flight hardware, of the ISS itself, or serious injury or loss of flight/ground personnel.

1S – A single point failure of a system/component designed to provide safety or protection capability against a potentially hazardous condition or event or a single failure point in a safety or hazard monitoring system that causes the system to fail to detect, or operate when needed during the existence of a hazardous condition that could result in loss (failure/damage) of flight hardware, of the ISS itself, or serious injury or loss of flight/ground personnel.

2 – A single point failure that could result in loss or partial loss of a mission critical function.

2R – Redundant items, all of which if failed, could result in loss or partial loss of a mission critical function.

3 – All others.

7.0 CRITERIA FOR CRITICAL ITEMS

Upon having completed the listing of failure modes and effects associated with the design, each item/system has been assessed according to a set of rules which are used to determine if am item is ***critical***. The rule or rules by which the assessment is made are referred to as the "Criteria for Critical Items". Items which are determined to be ***critical*** are listed separately on a ***critical items list***.

Critical items are items which, if they occur, could result in serious injury, loss of personnel, loss of facilities, or compromise the attainment of mission objectives.

The purpose of a Critical items List (CIL) is to call attention to specific failure modes whose effects are at a high level of severity. Critical Items must be considered and addressed in some manner either by (a) design change, or (b) by compensating provisions within design or operations.

Compensating provisions are 1. design features, 2. operational workarounds, 3. maintenance actions, 4. testing, 5. inspections, or 6. Off-nominal procedures which are developed to reduce risk or provide a corrective action in response to system level failure effects. For the FCF, the critical item criteria has been tailored from SSP 30234. The critical items criteria has been simplified and is defined as the following:

An item (a hardware device/system with associated failure mode) ***shall be judged to be critical if***:

It is a category 1, or 2 item.

It is a category 1R item which does not meet its failure tolerance requirement.

Criticality 1 and 2 items are single point failure points which could result in worst case effects that directly impact safety or ability to conduct particular scientific experiments.

8.0 FOMA FMEA WORKSHEETS

TABLE I. FMEA WORKSHEET FOR THE FOMA Premixed Fuel Supply Manifold

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Compensating Provision
Gas Bottle	GB2	Storage of Fuel/Premixed Fuel gas needed for experiments.	FOMA-01-1: Burst (rupture of cylinder)	1	Release of flammable gas into the CIR and possible ejection of projectiles at high velocity.	Possible damage to surrounding FOMA components and loss of premixed fuel gas supply needed for experiment. Inability to carry out experiments.	anomalous concentra-tion of pre-mixed fuel combined wit h an ignition source could cause a fire or explosion. Toxicity hazard. Ejecta and fire could inflict injury on crew, and/or damage ISS payloads.	Immediate effects such as pressure loss in pre-mix gas fill line registered by pressure transducers and PI2 pressure indicator, and/or visual indication that gas bottle has cracked open. TE = indeterminate, TD = 30sec. - 1 minute.	1.Structural failure. Stress cracking due to launch environment, or thermal effects. 2. Would shutdown the system, remove any possible ignition sources, remove damaged bottle, ventilate area, Inspect for damage, Conduct maintenance.
			FOMA-01-2: Leakage of cylinder	1R	Release of flammable gas into an air filled environment.	Worst case: Loss of premixed fuel gas supply needed f or experiment. Inability to carry out experiments.	Release of flammable gas in an air filled environment is a flammability hazard. (In the worst-case conditions of just enough fuel concentration and the existence of a possible ignition source.) The pre-mix fuel may also constitute a toxicity hazard.	Immediate or gradual pressure loss in pre-mix gas fill line registered by pressure transducers and PI2 pressure indicator, and/or visual indication that gas bottle has cracked open. TE and TD are indeterminate.	1.Structural failure. Stress cracking due to launch environment, or thermal effects. 2. Would shutdown the system, remove any possible ignition sources, remove damaged bottle, ventilate area, Inspect for damage, Conduct maintenance.
			FOMA-01-3: Provides Fuel gas supply Contaminated with undesired chemicals. (gaseous or particulate matter)	3	Contaminated premixed fuel gas is passed through the manifold gas line into the combustion chamber.	Worst case: Faulty scientific data obtained as a result of burns containing contaminants for an entire set of combustion experiments.	none	Faulty Scientific data would be obtained. PI or NASA Ground Ops Science staff may notice occurrence of anomalous burns or data readings, otherwise the faulty burn may not be re alized until scientific analysis of data. TE and TD are indeterminate.	1. Gas bottle did not meet Contamination Control Requirements 2. Shutdown system. Remove contaminated gas bottle. Run clean-up loop routine on the Chamber. Test contents with GC to verify clean up. Install new bottle and re-run experiment.

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Compensating Provision
Manual Valve	MV2	Manual control of gas flow out of gas bottle GB2.	FOMA-01-04: Valve fails closed.(stuck in closed position)	3	Inability to turn on gas supply from GB2.	Cannot provide gas supply from GB2 to the combustion chamber.	None	1.Astronaut cannot turn valve 2.Pressure transducers downstream on line show little or no pressure. TE=3-5 min., TD= 3-5 min.	1.Internal damage from launch vibration, corrosion, contamination (debris logged in valve mechanism) 2.would perform a safe removal of the gas bottle and install a spare.
			FOMA-01-05: Valve fails open. (Stuck in open position)	1S	Inability to manually turn off gas supply from GB2.	Inability to manually turn off gas supply from GB2 in the event of an emergency.	In the event of a rapid leak, it may be imperative to shut off gas flow at GB2. Inability to perform this function, may result in inability to combat a hazard.	1. Astronaut is unable to close valve 2.Pressure transducers downstream on line show little or no drop in pressure. TE is indeterminate, TD= 3-5 min.	1.Internal damage from launch vibration, corrosion, contamination (debris logged in valve mechanism) 2.shutdown the system, remove any ignition sources, remove damaged valve & bottle, ventilate area, Inspect for damage, Conduct maintenance.
			FOMA-01-06: External Leakage	1R	Leakage of fuel/premixed fuel gas into CIR.	Loss of fuel/premixed fuel gas needed for experiment.	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	Pressure transducers down-stream on fuel line show little or no increase in pressure during fill operation while all other indications appear to be normal. TE is indeterminate, TD = 3-5 minutes.	1.Internal/external damage to valve from vibration or corrosion provides a path for external leakage. 2.Would shutdown system, remove any possible ignition sources, ventilate area, Inspect for damage, and conduct maintenance.
			FOMA-01-07: Internal Leakage	1S	Leakage of fuel/premixed fuel gas into premix manifold line when valve is in closed state.	worst possible case: maximum internal leakage: Inability to manually turn off gas supply from GB2 in the event of an emergency.	In the event of a rapid external leak elsewhere in the FOMA, it may be imperative to shut off gas flow at GB2. Inability to perform this function, may result in inability to combat a hazard.	Pressure transducers downstream on line show little or no drop in pressure.TE is indeterminate, TD= 3-5 min.	1.Internal damage from launch vibration or corrosion.2.Would shutdown the system,remove any possible ignition sources,remove damaged valve & bottle, ventilate area, Inspect for damage, Conduct maintenance.

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Compensating Provision
			FOMA-01-08: Intermittent operation (Intermittently fails to open or close)	1S	Inability to turn on gas supply, or turn off gas supply from GB2.	Cannot provide gas supply from GB2 to the combustion chamber or inability to shut off gas supply in the event of an emergency.	In the event of a rapid external leak elsewhere in the FOMA, it may be imperative to shut off gas flow at GB2. Inability to perform this function, may result in inability to combat a hazard.	1.Valve fails to open or close (jammed), or 2.pressure transducers in the pre-mix manifold indicate that pressure does not rise or fall-off as it should.TE is indeterminate, TD= 3-15 minutes.	1.Wear, internal damage from vibration or corrosion.2.Would shutdown the system,remove any possible ignition sources,remove damaged valve & bottle, ventilate area, Inspect for damage, Conduct maintenance.
Quick disconnect	QD2	Transfer of fuel/pre-mixed fuel gas from GB2 into manifold line.	FOMA-01-09: Fails to allow a safe/correct and complete connection	3	Inability to transfer fuel/pre-mixed fuel gas from supply bottle GB2 to the manifold line	Cannot provide gas supply from GB2 to the Combustion Chamber resulting in the inability to start the fill operation and conduct experiment.	None	Visual: Astronaut would not be able to verify a complete connection of the gas bottle to the manifold. TE = 3-5 minutes, TD = 3-5 min.	1.Corrosion, wear, galling, or damage from launch vibration. 2. "Switch" to a spare gas bottle, repair, or remove and replace quick disconnect.
			FOMA-01-10: Fails to allow disconnection	3	Inability to disconnect the fuel/pre-mixed fuel gas bottle GB2 in order to install fuel gas bottle for the next experiment	Cannot proceed with experiments	None	Visual: Astronaut would not be able to disconnect the gas bottle from the manifold. TE = 3-5 minutes, TD = 3-5 min.	1.Corrosion, wear, galling, or damage from launch vibration. 2. Maintenance or removal and replacement of damaged QD.
			FOMA-01-11: External Leakage	1R	worst case: rapid leak--loss of pre-mixed fuel gas at a high rate.Leakage of flammable gas into the CIR.	worst case: Expendature of gas supply. Cannot provide correct amount of fuel/pre-mixed fuel gas from GB2 to the Combustion Chamber.	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	Best case: Pressure transducers would detect a loss of pressure on the line. Worst case: leak rate is very low and failure could go undetected. TE is indeterminate, TD = 3-5 minutes.	1.Corrosion, wear, galling, or damage from launch vibration. 2.shutdown the system,remove ignition sources,ventilate area, Inspect for damage, maintenance or removal and replacement of damaged QD.
			FOMA-01-12: Inhibits flow	3	Will not permit flow-through of pre-mixed gas	Cannot provide the correct amount of fuel/pre-mixed fuel gas from GB2 to the combustion chamber.Cannot perform experiments.	None.	Pressure transducers would not detect the expected build-up of pressure associated to flow. A check on other components in the line would reveal that the disconnect was clogged. TE = 3-5 min.,TD = 3-5 min.	1.Large debris contamination. Shock or damage following connection, causes internal slippage of parts.2. Repair of QD, or removal & replacement with new bottle assembly.

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Compensating Provision
Manual Valve	MV 14	Manual control of gas flow out of gas flow line to muffler MUF 4.	FOMA-01-13: Valve fails closed. (stuck in closed position)	3	Inability to manually transfer gas from the manifold line to muffler MUF4.	Cannot transfer trapped gas (between bottle and bottle QD)out of the manifold line. Cannot assure that pressure is below 40 psi.Cannot assure that QD can be safely disengaged. Cannot disengage QD. Cannot change bottles.Stops experiments.	None	1.visual: Astronaut cannot turn valve.2.)Valve appears to move but PI2 shows little or no pressure drop.TE = 3-5 min., TD = 3-5 min.	1.Internal damage to valve from vibration or shock, corrosion, or contamination (logged debris in valve mechanism)2. Corrective action: TBD.
			FOMA-01-14: Valve fails open. (Stuck in open position)	1R	worst case: valve failure goes undetected. Pre-mixed fuel gas is transferred from manifold line to muffler MUF 4 when it should not be.	Leakage of gas directly into CIR.1.Best case: Failure is detected within minutes by monitoring pressure transducers.Gas flow is shut off. 2.Failure goes undetected. When normal fill operations are resumed, gas needed for experiments is lost.	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	1.Visual: Astronaut cannot turn valve.2.)Valve appears to move but pressure transducers show unexpected readings when normal fill operation is resumed. TE is indeterminate, TD = 3-5 min.	1.Internal damage to valve from vibration or shock, corrosion, or contamination (logged debris in valve mechanism)2. Corrective action: safe shutdown, removal of any ignition sources, remove and replace or repair MV14.
			FOMA-01-15: External Leakage	1R	Leakage of pre-mixed fuel gas directly into the CIR	Leakage of gas directly into CIR.1.Best case: Failure is detected within minutes by monitoring pressure transducers.Gas flow is shut off. 2.Failure goes undetected. When normal fill operations are resumed, gas needed for experiments is lost.	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	Pressure transducers show unexpected readings when normal fill operation is resumed. TE is indeterminate. TD = 3-5 min.	1.Internal damage to valve from vibration or shock or corrosion.2. Corrective action: safe shutdown, removal of any ignition sources, remove and replace or repair MV14.

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Compensating Provision
			FOMA-01-16: Internal leakage	1R	Leakage of pre-mixed fuel gas directly to MUF 4 (a passive device) which immediately diffuses gas into the CIR.	Leakage of gas directly into CIR.1.Best case: Failure is detected within minutes by monitoring pressure transducers.Gas flow is shut off. 2.Failure goes undetected. When normal fill operations are resumed, gas needed for experiments is lost.	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	Pressure transducers show unexpected readings when normal fill operation is resumed. TE is indeterminate, TD = 3-5 min.	1.Internal damage to valve from vibration or shock or corrosion.2. Corrective action: safe shutdown, removal of any ignition sources, remove and replace or repair MV14.
			FOMA-01-17: Intermittent operation	1R	Inability to enable or shut off transfer of fuel/pre-mixed fuel gas from manifold line to MUF 4.	Best case: Can't bleed gas out of manifold line when required.Cannot reduce pressure of trapped gas.Worst case: Undetected valve failure (stuck open). Gas diffuses into CIR during normal chamber fill operation.Loss of fuel gas needed for experiments.	Worst case: 1.rapid external leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	Pressure transducers show unexpected readings when normal fill operation is resumed. TE is indeterminate. TD = 3-5 min.	1 Wear, iInternal damage to valve from vibration or shock or corrosion.2. Corrective action: safe shutdown, removal of any ignition sources, remove and replace or repair MV14.
Muffler	MUF 4	Passive device which diffuses gas from the manifold line into the CIR rack. This is to assure that trapped gas between GB2 and QD2 is reduced to a pressure below 40psi.	FOMA-01-18: Clogged (gas flow obstructed)	3	Inability to manually transfer gas from the manifold line to to the CIR rack in order to reduce pressure of trapped gas.	Cannot transfer trapped gas (between bottle and bottle QD)out of the manifold line. Cannot assure that pressure is below 40 psi.Cannot assure that QD can be safely disengaged. Cannot disengage QD. Cannot change bottles.Stops experiments.	None	Pressure indicator PI2 on pre-mixed fuel line shows that pressure has not been reduced. TE = indeterminate , TD = 3-5 minutes.	1. Contamination. 2. Corrective action: TBD.

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Compensating Provision
Pressure Indicator	PI2	Indicates internal pressure of gas bottle GB2 in order to give the crew an indication that the gas bottle may be diconnected from the manifold.	FOMA-01-19: Visual indicator remains recessed at a pressure above safe pressure threshold. (40psi)	1S	Provides incorrect indication.	worst case: pressure is too great for a safe disengagement of gas bottle from QD. Crew disconnects QD. Bottle is propelled away from QD and flight hardware is damaged.	worst case: The system effect causes a crew member to be injured and also damages flight hardware from another science payload.	PT4 and other pressure transducer readings on the manifold line, would also provide monitoring of bottle pressure.Disagreement between PI2 and pressure transducers on the line would indicate measurement error. TE is 3-5 sec.Best case TD = 3-5 minutes.	1.PI2 is not calibrated correctly, or spring is defective and performance is incorrect. 2.Would have to gradually bleed gas from GB2 through MV14 and MUF 4, until GB2 internal pressure was reduced below 40 psi.
			FOMA-01-20: Visual indicator goes to "out" position at a pressure below safe-pressure threshold. (40psi)	3	Provides incorrect indication.	Delay of experiment operations.	worst case: Failure is undetected. Disconnection of gas bottle GB2 is delayed. Crew proceedes with off-nominal operations. Eventually bottle is disconnected but this "Eats-up" crew time.	PT4 and other pressure transducer readings on the manifold line, would also provide monitoring of bottle pressure. Dis-agreement between PI2 and pressure trans-ducers on the line would indicate measurement error. TE is 3-5 sec.Best case TD = 3-5 minutes.	1.PI2 is not calibrated correctly, or spring is defective and performance is incorrect. 2. After de-termining that PI2 is reading higher than actual, and it is safe to disconnect GB2 at the QD, GB2 would be diconnected and removed.
			FOMA-01-21: Fails to activate.	1S	Provides no indication.	worst case: pressure is too great for a safe disengagement of gas bottle from QD. Crew disconnects QD. Bottle is propelled away from QD and flight hardware is damaged.	worst case: The system effect causes a crew member to be injured and also damages flight hardware from another science payload.	PT4 and other pressure transducer readings on the manifold line, would also provide monitoring of bottle pressure. Dis-agreement between PI2 and pressure trans-ducers on the line would indicate measurement failure. TE is 3-5 sec.Best case TD = 3-5 minutes	1.PI2 has a broken or defective spring. 2.Would have to gradually bleed gas from GB2 through MV14 and MUF 4, until GB2 internal pressure was reduced below 40 psi.

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Compensating Provision
			FOMA-01-21a: Intermittent operation	1S	Provides no indication.	worst case: pressure is too great for a safe disengagement of gas bottle from QD. Crew disconnects QD. Bottle is propelled away from QD and flight hardware is damaged.	worst case: The system effect causes a crew member to be injured and also damages flight hardware from another science payload.	PT4 and other pressure transducer readings on the manifold line, would also provide monitoring of bottle pressure. Dis-agreement between PI2 and pressure trans-ducers on the line would indicate measurement failure. TE is 3-5 sec.Best case TD = 3-5 minutes	1.PI2 has a defective spring. 2.Would have to gradually bleed gas from GB2 through MV14 and MUF 4, until GB2 internal pressure was reduced below 40 psi.
Pressure Transducers	PT 4,5 and 6	Provides measurement of Fuel/pre-mixed Fuel gas pressure within the manifold line.	FOMA-01-22: Incorrect measurement: indicates a pressure that is lower than actual.	1SR	Provides incorrect data to the FCU/IOP.	worse case: incorrect pressure data allows a pressure build-up on the line to go un-detected. High pressure stress on other line components results in external leakage. Loss of pre-mixed fuel gas needed for experiments.	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	Crew/Ops will expect a particular set of measurements (within uncertainty boundaries) as a function of time. [pressure vs. time curves] Measurement anomoly on transducers would be detectable. TE is indeterminate. TD = 3-5 minutes.	1.Transducer response drifts out-of-spec over time. 2. Pressure transducer would have to be removed and replaced or maintenace defered.
			FOMA-01-23: Incorrect measurement: Indicates a pressure that is higher than actual	3	Provides incorrect data to the FCU/IOP.	worst case: Delay of experiments as a result of transducer failure and the need to perform fault isolation/corrective action.	worst case: crew/ops believes that over-pressure condition exists and implements fault-isolation procedure.	Crew/Ops will expect a particular set of measurements (within uncertainty boundaries) as a function of time. [pressure vs. time curves] Measurement anomoly on transducers would be detectable. TE is indeterminate. TD = 3-5 minutes.	1. Transducer response drifts out-of-spec.2. Pressure transducer would have to be removed and replaced or maintenace defered.

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Compensating Provision
			FOMA-01-24: Failure to operate.	1SR	Provides no data to the FCU/IOP.	worse case: No pressure data allows a pressure build-up on the line to go un-detected. High pressure stress on other line components results in external leakage. Loss of pre-mix ed fuel gas needed for experiments.	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	Crew/Ops will expect a particular set of measurements (within uncertainty boundaries) as a function of time. [pressure vs. time curves] Measurement anomoly on transducers would be detectable. TE is indeterminate. TD = 3-5 minutes.	1. Loss of signal from transducer. 2.Pressure transducer would have to be removed and replaced or maintenace defered.
			FOMA-01-24-1: External Leakage	1R	worst case: failure goes undetected. Pre-mixed fuel gas leaks from transducer into FOMA and CIR.	Leakage of gas directly into CIR.1.Best case: Failure is detected within minutes by monitoring data from the other pressure transducers. 2.Failure goes undetected. When normal fill operations are resumed, gas needed for experiments is lost.	worst case: Expendature of gas supply. Cannot provide correct amount of fuel/pre-mixed fuel gas from GB2 to the Combustion Chamber.	Crew/Ops will expect a particular set of measurements (within uncertainty boundaries) as a function of time. [pressure vs. time curves] Measurement anomoly on transducers would be detectable. TE is indeterminate. TD = 3-5 minutes.	1.Vicon seal pressed against manifold and sealing face of transducer, is cracked, damaged, worn, or deteriorated.2. Pressure transducer would have to be removed and replaced or maintenace defered.
			FOMA-01-24-2: Intermittent open	1SR	Intermittent loss of output signal	loss of transducer output resulting in loss of or garbbled data	Crew may have missing or garbled data. worst case: all 3 pressure transducers fail in this manner. Unlikely, but possible. In this situation, crew is unable to monitor pressure profile during fill operation. Could be a loss of safety monitoring capability	Crew/Ops will expect a particular set of measurements (within uncertainty boundaries) as a function of time. [pressure vs. time curves] Measurement anomoly on transducers would be detectable. TE is indeterminate. TD = 3-5 minutes.	1.Temperature cycles and/or humidity with chemical contamination and action damages internal leads. Causes an intermittent contact condition.2.Pressure transducer would be removed & replaced or maintenace defered.

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			FOMA-01-24-3: Electrical short	1SR	Loss of output	Loss of pressure data	Crew will have missing data. worst case: all 3 pressure transducers fail.Unlikely, but possible. In this situation, crew is unable to monitor pressure profile during fill operation. Could be a loss of safety monitoring capability.	Crew/Ops will expect a particular set of measurements (within uncertainty boundaries) as a function of time. [pressure vs. time curves] Measurement anomoly on transducers would be detectable. TE is indeterminate. TD = 3-5 minutes.	1.Temperature cycles and/or humidity with chemical contamination and action damages internal leads. Causes an electrical short condition .2.Automatic: 24 volt power supply goes into current limiting condition and shuts off. Pressure transducer would be r
Filter	F2	Provides a filtering- out of debris that could be found in the fuel/pre-mixed fuel gas flowing through the line.	FOMA-01-25: Fails to stop contaminants	3	Contaminants are passed on through the fuel/premix fuel manifold	Debris in the form of small particles may contaminate com-ponents on the line and also accumulate in the combustion chamber. Experimental data from burns could be skewed or distorted.	None.	Observations and scientific measurements on experiment flames may indicate spectra that do not represent the intended purity of chemical composition.TE is indeterminate. TD is indeterminate.	1. Holes, damage, or deterioration of the filter.2.Remove and replace filter. Exhaust, run clean up loop, vent and re-fill chamber with contents from a spare gas bottle.
			FOMA-01-26:Clogged	3	worst case: obstructs or greatly reduces gas flow through the line.	Could stop fill operation for the combustion chamber, or greatly increase the fill time.	None.	Pressure transducers in the manifold and also in the chamber would show a low pressure. Would initiate fault isolation procedure for manifold components. TE is immediate. TD = 3 to 5 minutes.	1.Large and/or small size debris logged inside of filter.2.Remove and replace filter.
			FOMA-01-27: External Leakage	1R	worst case: rapid leak of flammable pre-mixed fuel gas into the CIR	worst case: rapid leak causes loss of fuel/pre-mixed fuel gas needed for the exper iment.	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	Pressure transducers in the manifold and also in the chamber would show a low pressure. Would initiate fault isolation procedure for manifold components. TE is immediate. TD = 3 to 5 minutes.	1.Cracking or rupture of filter assembly or defective seals. 2. safe shutdown, removal of any ignition sources, remove and replace filter.

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Solenoid Valves	SV 6,7,8	Control of gas flow and pressure through the manifold line	FOMA-01-28:Fails to open	3	Prohibits flow in the manifold line	Cannot provide gas to combustion chamber for burn. Stops experiment.	None.	Current-draw feedback signal monitored by computer. Indications from Pressure trans-ducers PT 25,28,and 29.TE = 3-5 min., TD = 3-5 min.	1.Coil burn out caused by wearout stresses.2. Solenoid valves are maintainable: Defective coils can be removed and replaced with a spare coil.
			FOMA-01-29: Fails to close	1R	Allows gas flow through manifold line when shutdown is intended	worst case: cannot reduce or stop flow of fuel gas into combustion chamber in an emergency	worst case: over-pressurization of the manifold and/or combustion chamber causes hazardous condition.	Current-draw feedback signal monitored by computer. Indications from Pressure trans-ducers PT 25,28,and 29.TE = 3-5 min., TD = 3-5 min.	1.Large debris or excessive contamination inside of valve.2.If required, the entire valve can be removed and replaced with a spare.
			FOMA-01-30: External Leakage	1R	worst case: rapid leak of flammable pre-mixed fuel gas into the CIR	Significant loss of fuel/premixed fuel gas needed for the experiment	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	Indications from Pressure transducers PT 25,28,and 29.TE is indeterminate. TD = 3-5 min.	1.Broken or cracked seals caused by changes in temperature or by vibration/shock induced impact.2.If required, the entire valve can be removed and replaced.
			FOMA-01-31: Internal Leakage	1R	Allows gas flow through manifold line when shutdown is intended	worst case: cannot reduce or stop flow of fuel gas into combustion chamber in an emergency	worst case: over-pressurization of the manifold and/or combustion chamber causes hazardous condition.	Indications from Pressure transducers PT 25,28,and 29.TE is indeterminate. TD = 3-5 min.	1.Large debris or excessive contamination inside of valve.2.If required, the entire valve can be removed and replaced with a spare.
			FOMA-01-32:Inter-mittent operation	1R	May allow gas flow in the line when shutdown is intended or may inhibit flow during fill operation	worst case: cannot reduce or stop flow of fuel gas into combustion chamber in an emergency	worst case: over-pressurization of the manifold and/or combustion chamber causes hazardous condition.	Indications from Pressure transducers PT 25,28,and 29.TE is indeterminate. TD = 3-5 min.	1.Temperature cycles and/or humidity with chemical contamination and action damages internal leads. Causes an intermittent contact condition.2.If required, the entire valve can be removed and replaced with a spare.

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			FOMA-01-32-1: Spurious opening-Valve opens randomly without intentional command	3R	Provides unncessary and unexpected fluid line connection.	Unable to maintain proper pressure/flow levels for test point accuracy. Loss of a test point.	None	Pressure transducer signal and software diagnostic. TE is immediate. TD = 3-5 min.	1.Uncontrolled computer command or damaged electronic relay. 2. Re-initialize software or remove and replace damaged relay.
			FOMA-01-32-2: Spurious Closing-Valve closes randomly without intentional command	3	Provides unncessary and unexpected fluid line closure.	Unable to maintain proper pressure/flow levels for test point accuracy. Loss of a test point.	None	Pressure transducer signal and software diagnostic. TE is immediate. TD = 3-5 min.	1.Uncontrolled computer command,damaged solenoid coil or electronic relay. 2. Re-initialize software, or remove and replace damaged coil or relay.
			FOMA-01-32-3: Valve opens too early (not in the operational sequence of the pre-mix manifold)	3R	Provides unncessary and unexpected fluid line connection.	Unable to maintain proper pressure/flow levels for test point accuracy. Loss of a test point.	None	Pressure transducer signal and software diagnostic. TE is immediate. TD = 3-5 min.	1.Uncontrolled computer command or damaged electronic relay. 2. Re-initialize software or remove and replace damaged relay.
			FOMA-01-32-4: Valve opens too late. (not within the operational sequence of the pre-mix manifold)	3	Hampers gas mixing operational sequence.	Unable to maintain proper pressure/flow levels for test point accuracy. Loss of a test point.	None	Pressure transducer signal and software diagnostic. TE is immediate. TD = 3-5 min.	1.Uncontrolled computer command or damaged electronic relay. 2. Re-initialize software or remove and replace damaged relay.
			FOMA-01-32-5: over-heating	3	worst case: Temperature of solenoid valve rises above permitted level.Monitoring thermistor shuts down the manifold.	1.Heat is transferred by the the mass of the manifold out of the area.2.The experiment is interrupted until the solenoid valve is removed and replaced. Loss of test point.	None.	1.Software diagnostic/monitoring by IOP/FCU. TE = 3 min., TD = 5 min.	1. Solenoid coil over-current /overheating.2.Remove and replace defective solenoid coil.
			FOMA-01-32-6: Electrical Short	3	Valve will not respond to software command.Unexpected valve closure.	Unable to continue testing.Loss of test point.	None.	Pressure transducer signal and software diagnostic. TE is immediate. TD = 3-5 min.	1.Solenoid coil insulation damage, damage to solenoid wiring, or damaged relay. 2. Remove and replace defective coil,wiring,or relay.

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Pressure Regulator	PR2	Regulate fuel/pre-mixed fuel gas pressure from 2000 PSI to 100 PSI.	FOMA-01-33: Fails to regulate pressure down to specified 100 PSI.	1R	Build-up of pressure in gas line: possible over-pressurization.	weakness in manifold line or any of its components, in combination with a large build-up in pressure leads to leakage of pre-mixed fuel gas.	worst case: over-pressurization of the manifold and/or combustion chamber causes hazardous condition.	PT 5 and 6 would measure an over-pressure condition. TE is indeterminate, TD= 3-5 min.	1.Loss of initial setting (drifts out-of-cal.) or loose internal parts from launch vibration. 2.Detection of over-pressure condition by pressure switch will sh ut solenoid valves on the line.Pressure reg-ulator can be removed and replaced.
			FOMA-01-34:Over-regulates pressure far below 100 PSI.	3	Reduction of flow rate inputed to Mass flow controller	Partial loss of some test points or delay of experiment.	None.	PT 5 and 6 would measure an under-pressure condition. TE is indeterminate, TD= 3-5 min.	1.Loss of initial setting (drifts out-of-cal.) or loose internal parts from launch vibration. 2.Pressure reg-ulator can be removed and replaced.
			FOMA-01-35: External Leakage	1R	Reduction of flow rate inputed to Mass flow controller	Loss of fuel/pre-mixed fuel gas needed for experiment.	Non-detection of the leakage may result in a flammability or toxicity hazard to crew.	PT 5 and 6 would measure an under-pressure condition. TE is indeterminate, TD= 3-5 min.	1.Broken or cracked seals caused by changes in temperature or by vibration/shock induced impact.2.If required, the regulator can be removed and replaced.
Pressure Switch	PS2	Provides the computer a cap-ability to shut sol-enoid valves if pressure down-stream of PR2 exceeds 100 PSI or setting.	FOMA-01-36: Fails to switch solenoid valves to closed position	1R	Build-up of pressure in gas line: possible over-pressurization.	Loss of functionality on a hazard monitoring and control component. May not operate when required to operate in order to combat a potentially hazardous condition.	None.However, in a situation where the pressure regulator has failed, failure of the pressure switch could result in an over-pressure condition in the manifold.	Data from pressure transducers on the manifold line would provide an indication that pressure was building up and there is an off-nominal condition.TE = 3 min., TD = 5 min.	1.Electrical short, loss of signal, internal mechanism of switch is jammed. 2.) Off-nominal procedure for clean-up and vent. Remove and replace PS2. Re-run fill operation.
			FOMA-01-37: External Leakage	1R	Reduction of flow rate inputed to Mass flow controller	Loss of fuel/pre-mixed fuel gas needed for experiment.	Non-detection of the leakage may result in a flammability or toxicity hazard to crew.	PT 5 and 6 would measure an under-pressure condition. TE is indeterminate, TD= 3-5 min.	1.Broken or cracked seals caused by changes in temperature or by vibration/shock induced impact.2.If needed, PS2 can be removed and re-placed.

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Mass Flow Controller	MFC1	Meters mass flow of Fuel/pre-mixed Fuel gas to combustion chamber for experiments	FOMA-01-38: Reads mass flow as higher than actual	3	None.	Incorrect measurement of the total fuel/pre-mixed fuel mass involved in the experiment. Results in "skewed'/erroneous scientific results.	None.	Data from PT25, 28, and 29 will not be consistent with mass flow rate measured by MFC1. TE = 3-5 min., TD = 5 min.	1. MFC1 calibration drift, incorrect calibration, or failure to calibrate.2. IOP/crew will not enable ignition: will fault isolate to MFC1. Re-calibrate, or remove and replace.
			FOMA-01-39: Reads a mass flow that is lower than actual	3	None.	Incorrect measurement of the total fuel/pre-mixed fuel mass involved in the experiment. Results in "skewed'/erroneous scientific results.	None.	Data from PT25, 28, and 29 will not be consistent with mass flow rate measured by MFC1. TE = 3-5 min., TD = 5 min.	1. MFC1 calibration drift, incorrect calibration, or failure to calibrate.2. IOP/crew will not enable ignition: will fault isolate to MFC1. Re-calibrate, or remove and replace.
			FOMA-01-40: Allows too much flow	3	Flow output is greater than set-point. Internal control valve tries to close.	Incorrect gas mixture in the combustion chamber results in "skewed" or eroneous scientific results.	None	PT 25,28 and 29 will indicate a pressure that is much higher than expected for the correct mass flow rate. TE=3-5 minutes, TD = 5 minutes.	1. Internal valve sticks from corrosion or contam-ination. 2. IOP/Crew will not enable ignition. Will fault isolate to MFC1. Will remove and replace.
			FOMA-01-41: Allows too little flow	3	Flow output is less than set-point. Internal control valve tries to open.	Incorrect gas mixture in the combustion chamber results in "skewed" or eroneous scientific results.	None	PT 25,28 and 29 will indicate a pressure that is much lower than expected for the correct mass flow rate. TE=3-5 minutes, TD = 5 minutes.	1. Internal solenoid valve fails to open or opens only partially due to burned out or damaged coil.2.IOP/Crew will not enable ignition. Will fault isolate to MFC1. Will remove and replace.
			FOMA-01-42: Intermittent Flow	3	cycled output of mass flow controller	Incorrect gas mixture in the combustion chamber results in "skewed" or eroneous scientific results.	None	PT 25,28 and 29 will indicate a pressure vs. time profile that does not agree with the correct mass flow rate. TE=3-5 minutes, TD = 5 minutes.	1. Internal solenoid valve operates intermittently due to open circuit or coil damage. 2.IOP/Crew will not enable ignition. Will fault isolate to MFC1. Will remove and replace.

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			FOMA-01-43: External Leakage	1R	Release of flammable gas into an air filled environment.	Loss of premixed fuel gas needed for experiment leading to incorrect gas mixture in chamber.	worst case: 1.rapid leak 2.anomalous concentration 3.presence of ignition source leads to: fire, toxic threat, Crew injury, and damage of other payloads.	PT 25,28 and 29 will indicate a low pressure vs. time profile that does not agree with the correct mass flow rate. TE=3-5 minutes, TD = 5 minutes.	1.Broken or cracked seals caused by changes in temperature or by vibration/shock induced impact. 2.IOP/Crew will not enable ignition. Will fault isolate to MFC1. Will remove and replace
			FOMA-01-43-1: Intermittent readings of mass flow data	3	None.	Incorrect measurement of the total fuel/pre-mixed fuel mass involved in the experiment. Results in "skewed'/erroneous scientific results.	None	Data from PT25, 28, and 29 will not be consistent with mass flow rate measured by MFC1. TE = 3-5 min., TD = 5 min.	1. Intermittent internal circuit connection due to damage or chemical action from contamination. 2.IOP/crew will not enable ignition: will fault isolate to MFC1. Re-calibrate, or remove and replace.
			FOMA-01-43-2: electrical- Short	3	Internal solenoid Valve will not respond to software command.Unexpected valve closure.	Unable to continue testing.Loss of test point.	None.	Pressure transducer signal and software diagnostic. TE is immediate. TD = 3-5 min.	1.Solenoid coil insulation damage, damage to solenoid wiring, or damaged relay. 2. Remove and replace defective coil,wiring,or relay,or remove and replace mass flow controller.
Vacuum Switch		Resets timers which will enable solenoid valves to open on command and start fuel/pre-mixed fuel gas flow operation.	FOMA-01-44: Fails to reset timers.	3	Timers are not reset and solenoid valves SV7 and 8 are not enabled and cannot open.	Cannot provide gas to combustion chamber for burn. Stops experiment.	None.	IOP/FCU will not get "hand-shake" signal to confirm that timers have been reset. TE < 1 minute. TD = 3-5 min.	1.Internal contamination or corrosion leading to short, arcing, and then open circuit.2.Remove and replace vacuum switch
			FOMA-01-45: Uncontrolled and repeated resets	1R	worst case: Allows timer to be reset a number of times during a fill operation	Defeats a safety inhibit for controlling gas flow time.	Under anamolous pressure conditions in the chamber, failure to inhibi gas flow may contribute to a over-pressurization hazard.	IOP/FCU would get repeated "hand-shake" signal to indicate that timers have been reset. TE < 1 minute. TD = 3-5 min.	1.Internal contamination or corrosion leading to shorting. 2.Remove and replace vacuum switch

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Timers	on SV7 and 8	Safety Inhibit: Prohibits total fuel mass in chamber from exceeding safe limits. (limits flow time)	FOMA-01-46: Timer fails to re-set to a new count level after counting down to zero.	3	Solenoids SV7 and SV8 cannot open.	Cannot provide gas to combustion chamber for burn. Stops experiment.	none	IOP/FCU will not get "hand-shake" signal to confirm that timers have been reset. TE < 1 minute. TD = 3-5 min.	1.Internal contamination, or over-temperature condition causing shorting,arcing, and damage on micro-controller, relay, or crystal oscillator, leading to open circuit. 2.Fault Isolate to timers. Remove and replace timers.
			FOMA-01-47: Timer sends early signal to close solenoid valves.	3	Early shutdown of fuel/pre-mixed fuel gas flow.	Incorrect test conditions.Ignition may provide scientific data that is skewed or inaccurate.	None	IOP/FCU will receive early signal that timer has closed solenoid valves on the line. TE < 1 minute. TD = 3-5 min.	1.Internal contamination, or over-temperature condition on micro-controller, relay, or crystal oscillator, causing a short. 2.Fault Isolate to timers. Remove and replace timers.
			FOMA-01-48: Timer sends late signal to close solenoid valves	1R	worst case: safety inhibit is defeated when needed.	worst case: Fuel mass transferred to chamber exceeds specified limit. Incorrect test conditions.Ignition may provide scientific data that is skewed or inaccurate.	Under anomalous pressure and fuel-to-oxygen ratio, a hazard may be created during ignition.	IOP/FCU will receive late signal that timer has closed solenoid valves on the line. TE < 1 minute. TD = 3-5 min.	1.Internal contamination, or over-temperature condition on micro-controller, relay, or crystal oscillator, causing a intermittent open circuit. 2.Fault Isolate to timers. Remove and replace timers.
			FOMA-01-49: Uncontrolled and spontaneous resets.	1R	worst case: safety inhibit is defeated. Timer keeps re-setting so flow time is not limited.	worst case: Fuel mass transferred to chamber exceeds specified limit. Incorrect test conditions.Ignition may provide scientific data that is skewed or inaccurate.	Under anomalous pressure and fuel-to-oxygen ratio, a hazard may be created during ignition.	IOP/FCU will receive multiple signals indicating that timer has reset. TE < 1 minute. TD = 3-5 min.	1.Internal contamination, or over-temperature condition on micro-controller, relay, or crystal oscillator, causing intermittent shorts. 2.Fault Isolate to timers. Remove and replace timers.
			FOMA-01-49-1: Overheating	1R	worst case: Overheating causes timer to fail. safety inhibit is defeated when needed.	worst case: Fuel mass transferred to chamber exceeds specified limit. Incorrect test conditions.Ignition may provide scientific data that is skewed or inaccurate.	Under anomalous pressure and fuel-to-oxygen ratio, a hazard may be created during ignition.	IOP/FCU will receive intermittent, distrorted /noisy, or NO signal indicating that timer has failed. TE < 1 minute. TD = 3-5 min.	1. Internal electronic components of timer are not rated for operational voltages, currents,and ambient temperatures. 2.Defective Timer would have to be removed and replaced with a spare.

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			FOMA-01-49-2 : Electrical Short	1R	worst case: Electrical short internally damages timer and causes timer to fail. Safety inhibit is defeated when needed.	worst case: Fuel mass transferred to chamber exceeds specified limit. Incorrect test conditions.Ignition may provide scientific data that is skewed or inaccurate.	Under anomalous pressure and fuel-to-oxygen ratio, a hazard may be created during ignition.	IOP/FCU will receive intermittent, distrorted /noisy, or NO signal indicating that timer has failed. TE < 1 minute. TD = 3-5 min.	1.Internal contamination, or over-temperature condition on micro-controller, relay, or crystal oscillator, causing intermittent shorts. 2.Fault Isolate to timers. Remove and replace timers.
Thermisto r	TM-5	Temperature monitoring of fuel/ pre-mix fuel manifold	FOMA-01-50: Measurement Drift: Measurement indicates a temperature that is higher than actual	3	None.	loss of temperature monitoring capability.	No direct affect on station/crew but provides incorrect data in the event of some temperature anomaly.	Temperature measure-ment will not be consistent with all other indications from other sensors. TE and TD are indeterminate.	1.Thermal cycles which cause cracks, drifting in resistance, and measurement drift.2. May elect no action or removal and replacement.
			FOMA-01-51: Measurement Drift: Measurement indicates a temperature that is lower than actual	3	None.	loss of temperature monitoring capability.	No direct affect on station/crew but provides incorrect data in the event of some temperature anomaly.	Temperature measure-ment will not be consistent with all other indications from other sensors. TE and TD are indeterminate.	1.Thermal cycles which cause cracks, drifting in resistance, and measurement drift.2. May elect no action or removal and replacement.
			FOMA-01-52:No output	3	None.	loss of temperature monitoring capability.	No direct affect on station/crew but provides incorrect data in the event of some temperature anomaly.	Loss of temperature data. No signal. TE and TD are indeterminate.	1.Electrical overstress, moisture intrusion, open circuit resulting from internal damage. 2. Can remove and replace thermistors.
			FOMA-01-53: overheating	3	None.	loss of temperature monitoring capability.	No direct affect on station/crew but provides incorrect data in the event of some temperature anomaly.	Loss of temperature data. No signal. TE and TD are indeterminate.	1.Electrical overstress 2. Can remove and replace thermistors.
			FOMA-01-54: Electrical short	3	None.	loss of temperature monitoring capability.	No direct affect on station/crew but provides incorrect data in the event of some temperature anomaly.	Loss of temperature data. No signal. TE and TD are indeterminate.	1. Not rated for oper-ating voltage /currents, deteriorated insulation, moisture,or chemical contamination 2. Can remove and replace thermistors.

TABLE II. FMEA WORKSHEET FOR THE FOMA Nitrogen Supply Manifold

*MIL-STD-1522A test requirement modified as per NSTS 1700.7B paragraph 208.4.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
Nitrogen supply		**FOMA-02**								
Quick Disconnect: GN2 supply from space station	Transfer of N2	FOMA-02-1	Fails to allow correct connection.	2R	Cannot open GN2 manual valve if we know N2 leakage is possible. Loss of function. (N2 flow)	Cannot access N2 supply from space station. Loss of test points.	TBD	Corrosion, premature wear, galling.	Visual and immediate effect. TE = TDB TD = TBD	Maintenance /replacement of quick disconnect required.
GN2 Supply Manual Valve	Manual control of N2 flow out from space station supply.	FOMA-02-3	Valve fails closed. (stuck in closed position)	2R	Inability to manually turn on N2 flow from space station supply.	Loss of ability to provide N2 from space station supply to Chamber. Loss of certain test points.	TBD	Contamination and Corrosion.	Transducers show no/little pressure TE = TDB TD = TBD	Must be able to remove failed valve and replace it or conduct other experiments using the Diluent/ premixed gas supply manifold.
GN2 Supply Manual Valve	Manual control of N2 flow out from space station supply.	FOMA-02-4	Valve Leakage	1R Note: SSP 57025 limits the flow rate and atmosphere will be checked for high N2/low O2. We will check before opening rack with monitor.	Loss of N2 from space station supply. N2 leakage into cabin constitutes a hazard. Worst case- The N2 could fill the cabin forming a oxygen depleted zone.	Incorrect amount of N2 added to mixture in combustion chamber. If burn were to take place, scientific data could be flawed since burn took place with incorrect fraction of N2.	TBD	Contamination, Corrosion, or galling.	Transducers show reduced pressure from what is expected. TE = TDB TD = TBD	Shut down fill operation. Remove and replace faulty manual valve. Exhaust, clean, and vent the faulty gas mixture in the chamber. Re-fill and implement intended experiment.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
GN2 Supply Space Station	Provide N2 as Diluent for combustion experiments	FOMA-02-5	Provides contaminated supply	2R	Contaminated N2 may be passed on to chamber	Faulty scientific data as a result of burns containing contaminants	TBD	N2 supply from space station did not meet contamination control requirements.	Faulty scientific data. TE = T DB TD = TBD	F4 Provides Filtering of N2 carried in line.
Flexible Hose	Transfer of N2 from space station QD to QD4.	FOMA-02-6	Cracked and Leaking	1R	Loss of N2 from space station supply. The N2 could fill the cabin forming a oxygen depleted zone.	Incorrect amount of N2 added to mixture in chamber. If burn were to take place, scientific data could be flawed since burn took place with incorrect fraction of N2.	TBD	Deterioration related to chemical action, premature wear, undetected damage or weakness.	Transducers show reduced pressure from what is expected. TE = TDB TD = TBD	Shut down N2. Removal & replacement of defective flexible hose OR conduct other experiments using the Diluent/ premixed gas supply manifold.
Quick Disconnect QD4	Transfer of N2 from space station supply to Nitrogen/High Pressure Supply Manifold.	FOMA-02-7	Fails to allow correct connection.	2R	Cannot open GN2 manual valve if we know N2 leakage is possible. Loss of function. (N2 flow)	Cannot access N2 supply from space station. Loss of test points.	TBD	Corrosion, premature wear, galling..	Visual and immediate effect. TE = TDB TD = TBD	Removal and replacement of quick disconnect required. Conduct other experiments using the Diluent/ premixed gas supply manifold.
PI4 Pressure Indicator	To provide indication to crew that pressure at QD4 is low enough to permit demate at QD4.	FOMA-02-8	Indicates a pressure that is higher than actual	3	Provides incorrect data to the crew	Timing of QD4 demate will be questioned.	TBD	Spring performance incorrect.	PT10 Transducer reading relayed to crew by computer. Comparison with PI4. TE = TDB TD = TBD	Transducer would indicate true pressure. Crew would be informed that it is safe to disconnect QD4. Remove and replace faulty pressure indicator.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
PI4 Pressure Indicator	To provide indication to crew that pressure at QD4 is low enough to permit demate at QD4.	FOMA-02-9	Indicates a pressure that is lower than actual.	1R	Provides incorrect data to crew.	May not be able to disconnect QD4. Disconnection could result in N2 leakage.	TBD	Spring performance incorrect.	PT10 Transducer reading relayed to crew by computer. Comparison with PI4 reading. TE = TDB TD = TBD	The QDs are self sealing. If they were able to be disconnected, they would not Leak significant N2.
PI4 Pressure Indicator	To provide indication to crew that pressure at QD4 is low enough to permit demate.	FOMA-02-10	No indication. PI 4 inoperative.	1R	Provides no data to crew	May not be able to disconnect QD4. Disconnection could result in N2 leakage.	TBD	Broken internal spring.	PT 10 Transducer reading relayed to crew by computer. TE = TDB TD = TBD	PT10 pressure transducer would provide a monitoring of input pressure. Would indicate if QD4 can be safely disconnected.
PT10 Pressure Transducer	Provides an exact measurement of pressure	FOMA-02-11.	Indicates a pressure that is higher than actual	2R	Provides incorrect data to computer and/or crew	Could conceivably cause computer to shut down gas supply and lose some test points.	TBD	Performance drifts out of specification.	Data from other Pressure transducers on the line would contradict PT10. TE = TDB TD = TBD	Remove and replace faulty transducer. Would need a procedure to re-open valves and clear erroneous data from computer to re-start fill operation.
PT10 Pressure Transducer	Provides an exact measurement of pressure	FOMA-02-12.	Indicates a pressure that is lower than actual.	1R Pressure from station supply Limited to 120psi.= chamber MDP.	Provides incorrect data to computer and/or crew.	N2 pressure in line could build up without crew knowledge in the event that PI 4 has failed. Possible Hazard.	TBD	Performance drifts out of specification.	Data from other Pressure transducers on the line would contradict PT10. TE = TDB TD = TBD	Remove and replace the faulty PT 10. Would need a procedure to re-open valves and clear erroneous data from computer to re-start fill operation.
Item	**Function**	**Failure mode No.**	**Failure Mode**	**Crit.**	**Local Effect**	**System Effect**	**Station/Crew Effects**	**Potential Causes**	**Detection Method/Time to Effect = TE, Time to Detect = TD**	**Compensating Provision**

PT10 Pressure Transducer	Provides an exact measurement of pressure	FOMA-02-13.	No output. PT 10 inoperative.	1R	Provides NO data to computer and/or crew.	N2 pressure in line could build up without crew knowledge in the event that PI 4 has failed. Possible Hazard.	TBD	Loss of signal. May be caused by open-circuit failure.	Data from other Pressure transducers on the line would contradict PT10. TE = TDB TD = TBD	Remove and replace the faulty PT 10. Would need a procedure to re-open valves and clear erroneous data from computer to re-start fill operation.
F4 Filter	Provides Filtering of gas transferred through line	FOMA-02-15.	fails	3	Contaminants are passed on through the line in small amounts.	Some inaccuracy in scientific data as a result of burns containing small contaminants	TBD	Partial damage	"Skewed" data or inaccuracies may initiate trouble-shooting TE = TDB TD = TBD	Filter is replaceable. Exhaust, clean, vent, and re-fill.
F4 Filter	Provides Filtering of gas transferred through line	FOMA-02-16.	fails	2R	Stops or greatly reduces gas flow to mass-flow controller	Could affect fill time for combustion chamber	TBD	Large size contamination and/or debris inside filter	Troubleshooting procedure for FOMA-02 TE = TDB TD = TBD	Filter is replaceable. Can also run other experiments using diluent/premixed gas supply manifold.
SV13,12, or 2 Solenoid Valves	Control of N2 flow (pressure)	FOMA-02-17	fails	2 R	Inability to provide N2 gas for experiments	Loss of test points. Would have to switch over to diluent/premixed gas supply manifold.	TBD	Coil Burn out. (may be caused by premature wear of coil)	Current draw feedback monitored by computer, pressure transducers indication downstream. TE = TDB TD = TBD	Design of Solenoid Valves is maintainable: Defective coils can be removed and replaced with spare coil. Can also run other experiments using diluent/premixed gas supply manifold.
SV13,12, or 2 Solenoid Valves	Control of N2 flow (pressure)	FOMA-02-18	fails	1R	Allows N2 flow to reduced level when shut down is intended.	Could be a contributing cause to a hazard.	TBD	Large Debris or excessive contamination on seat.	Pressure transducers indication downstream. TE = TDB TD = TBD	Design of Solenoid Valves is maintainable: If valve will not close due to failure, entire valve can be re-moved and replaced.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
SV13,12, or 2 Solenoid Valve	Control of N2 flow (pressure)	FOMA-02-19	fails	1R Note: If a leak is strongly suspected from other observations, the experiment would be shut down and Leak checks would be performed.	N2 leakage into cabin constitutes a hazard. Worst case- The N2 could fill the cabin forming a oxygen depleted zone.	Detection of leak may necessitate system shutdown. Non-detection of leak may result in oxygen depletion threat in the worst case. Inability to perform experiments.	TBD	Broken seals, cracked seals, caused by inherent design weakness like sensitivity to changes in temperature or vibration.	Pressure transducers downstream like PT 15,28, and 29 would indicate low pressure TE = TDB TD = TBD	Design of Solenoid Valves is maintainable: If valve is leaking, due to seal failure, entire valve can be removed and replaced. External GN2 manual valve would be shut immediately.
PR 4 Pressure Regulator	Regulate N2 gas pressure from 2000 PSI to 120-140 PSI.	FOMA-02-20	fails	1R	Buildup of pressure in gas line. Possible over-pressurization	Detection of over-pressure condition by pressure switch PS 4 will shut solenoid valves on line.	TBD	Loss of initial setting. Loose internal parts from launch vibe.	PT 11, and 12 would measure over pressure. TE = TDB TD = TBD	Any pressure over specified amount for ex-periment and all solenoids shut. Pressure regulator can be replaced.
PR4 Pressure Regulator	Regulate N2 gas pressure from 2000 PSI to 120-140 PSI.	FOMA-02-21	fails	2R	Reduction of flow rate to mass flow controller.	Delay of test points. If regulator has failed would have to switch over to diluent/premixed gas supply manifold until regulator could be removed and replaced.	TBD	Loss of initial setting. Loose internal parts from launch vibe	PT 11, and 12 would measure low pressure. TE = TDB TD = TBD	Re-set pressure regulator. Second failure may necessitate removal and replacement.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
PT 27 Pressure Transducer	Provides an exact measurement of pressure across the diaphragm. Used to detect diaphragm rupture.	FOMA-02-22	fails	2R	Provides incorrect data to computer and/or crew	Inability to detect rupture of pressure regulator diaphragm.	TBD	Leaking, loss of signal, performance drifts out of spec.	Data from other Pressure transducers on the line would contradict PT27. TE = TDB TD = TBD	PT27 reading a lower pressure would indicate a detection failure of the pressure transducer and this item would be replaced.
PT27 Pressure Transducer	Provides an exact measurement of pressure across the diaphragm. Used to detect diaphragm pressure.	FOMA-02-23	fails	2R	Provides incorrect data to computer and/or crew.	Could conceivably cause computer to command solenoid valves to close and shut off N2 supply.	TBD	Leaking, loss of signal, performance drifts out of spec.	Data from other Pressure transducers on the line would contradict PT27. TE = TDB TD = TBD	Would replace PT 27. If problem persisted, then PR 4 would be replaced.
PT27 Pressure Transducer	Provides an exact measurement of pressure across the diaphragm. Used to detect diaphragm rupture.	FOMA-02-24	fails	2	Provides NO data to computer and/or crew.	Inability to detect rupture of pressure regulator diaphragm.	TBD	Leaking, loss of signal, performance drifts out of spec. May be caused by open-circuit failure.	Data from other Pressure transducers on the line would contradict PT27. TE = TDB TD = TBD	Would need a procedure to re-place PT27. Re-open valves and clear erroneous data from IOP to re-start fill operation.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
PS4 Pressure Switch	Would provide computer the capability to shut solenoid valves if pressure downstream of PR4 exceeds ___ PSI.	FOMA-02-25	fails	1R	Buildup of N2 pressure in gas line. Possible over-pressurization. Reliance now on PT11 to shut solenoid valves.	May allow gas pressure on line to build up and presents a hazard in the event of PT 11 failure. Threat of possible over-pressurization.	TBD	Leaking, loss of signal, performance drifts out of spec.	Data from Pressure transducers on the line would indicate loss of pressure control. TE = TDB TD = TBD	Would need a procedure to re-place PS4. The pressure regulator and PT/computer are back up.
PT11,PT12 Pressure Transducers	Provides an exact measurement of pressure	FOMA-02-26	fails	1R	Provides incorrect data to computer and/or crew	Could conceivably allow build up of pressure on line without crew knowledge. Possible Hazard	TBD	Leaking, loss of signal, performance drifts out of spec.	PT 15, 28, & 29 readings will not be consistent with PT 11 or 12. TE = TDB TD = TBD	Would need a procedure to re-place PT11 or 12. Re-open valves and clear erroneous data from IOP to re-start fill.
PT11,PT12 Pressure Transducers	Provides an exact measurement of pressure	FOMA-02-27	fails	2R	Provides incorrect data to computer and/or crew	Could conceivably cause computer to command solenoid valves to close and shut off gas supply.	TBD	Leaking, loss of signal, performance drifts out of spec.	PT 15, 28, & 29 readings will not be consistent with PT 11 or PT12. TE = TDB TD = TBD	Would need a procedure to re-place PT11 or 12. Re-open valves and clear erroneous data from IOP to re-start fill operation
PT11, PT12 Pressure Transducers	Provides an exact measurement of pressure	FOMA-02-28	fails	1R	Provides NO data to computer and/or crew.	Gas pressure in line could build up without crew knowledge	TBD	Loss of signal caused by open-circuit failure.	PT 15, 28, & 29 readings will not be consistent with PT 11 & 12. TE = TDB TD = TBD	Would need a procedure to re-place I/O card in the FCU and/or PT11 & 12. Re-open valves and clear erroneous data from IOP to re-start fill operation

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
MFC4: Mass flow controller	Meters mass flow of N2 gas to combustion chamber for experiments	FOMA-02-29	fails	2R	Flow output is greater than set-point. Control valve tries to close.	Incorrect test conditions due to incorrect gas flow. Mass of N2 gas in chamber may exceed requirement for test point. Over pressurization still controlled by regulator, pressure switch and PT/computer.	TBD	1.Internal control valve coil does not electrically respond or does not respond correctly to closure signal. 2.Internal valve has corrosion or contamination.	PT 15, 28, & 29 readings will indicate rapid build-up of pressure. TE = TDB TD = TBD	N2 content will be checked. IOP & crew will not enable ignition. Fault Isolate to MFC4 and replace MFC4. Over pressur-ization controlled by PS4, PR4, and PT/computer
MFC4: Mass flow controller	Meters mass flow of N2 gas to combustion chamber for experiments	FOMA-02-30	fails	1R	Flow output is less than set point. Control valve tries to open.	Too little N2 could cause a high fuel – O2 mixture. Possible Hazard.	TBD	Internal solenoid fails to open/ will not open com-pletely. (Burned out or damaged coil.)	PT 15, 28, & 29 readings will indicate pressure is too low. TE = TDB TD = TBD	N2 mixture ratio will be verified. IOP & crew will hold up ignition. Fault Isolate to MFC4 and replace MFC4.
MFC4: Mass flow controller	Meters mass flow of N2 gas to combustion chamber for experiments	FOMA-02-31	fails	2R	Principle Investigator stationed on ground, may not notice that values are too high.	Could lead to incorrect measure-ment of the total N2-mass involved in experiment. PI would get skewed scientific results. Switch over to experiments using diluent /pre-mixed gas supply manifold.	TBD	MFC calibrated incorrectly, or not calibrated. MFC output drifts out of specification. MFC damaged by launch vibe.	PT 15, 28, & 29 readings will indicate expected pressure in line and will not agree with MFC4. TE = TDB TD = TBD	N2 mixture ratio will be verified. IOP & crew will not enable ignition. Fault Isolate to MFC4 . Re-calibrate MFC4 or remove and replace MFC4.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
MFC4: Mass flow controller	Meters mass flow of N2 gas to combustion chamber for experiments	FOMA-02-32	fails	2R	Principle Investigator stationed on ground, may not notice that values are too low.	Could lead to incorrect measure-ment of the total N2-mass involved in experiment. PI would get skewed scientific results. Switch over to experiments using Diluent Premixed gas supply manifold.	TBD	MFC calibrated incorrectly, or not calibrated. MFC output drifts out of specification. MFC damaged by launch vibe.	PT 15, 28, & 29 readings will indicate expected pressure and will not agree with MFC4. TE = TDB TD = TBD	IOP & crew will not enable ignition. Fault Isolate to MFC4. Re-calibrate MFC4 or remove and replace manifold.
MFC4: Mass flow controller	Meters mass flow of N2 gas to combustion chamber for experiments	FOMA-02-33	fails	2R	PT 15, 26, and 27 read low pressure.	Unable to perform experiment without N2. Cannot start ignition. Would have to initiate fault isolation or switch over to experiments using Diluent/Premixed gas supply manifold.	TBD	Internal solenoid will not open due to a burned out or damaged coil.	Pressure transducers upstream of MFC4 read positive pressure but readings downstream show little or no pressure. TE = TDB TD = TBD	IOP & crew will not attempt ign ition. Will Fault Isolate to MFC4. Remove faulty MFC4 and replace with good Mass flow controller.
Check Valve CV8.	Prevents gases from other manifolds from back-flushing into the N2 high pressure supply manifold.	FOMA-02-34	fails	2R	Loss of protection from back-flushing effect.	WC: May necessitate shutdown of Nitrogen/High Pressure Manifold. Switch over to use of the Diluent Premixed gas supply manifold.	TBD	Large Debris or excessive contamination on seat.	An unexpected rise in pressure would be detected by PT 12. TE = TDB TD = TBD	IOP & crew will not attempt ignition. Will Fault Isolate to timers. The primary control of the fuel amount is the MFC1.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
Check Valve CV8.	Prevents gases from other manifolds from back-flushing into the N2 high pressure supply manifold.	FOMA-02-35	fails	2R	Cannot flow N2 into combustion chamber.	Forced to either Fault Isolate or switch over to experiments that use the diluent/pre-mixed gas supply manifold.	TBD	Internal failure of electronics or mechanical parts.	PT 15, 28, and 29 report incorrect pressure profile in combustion chamber. TE = TDB TD = TBD	IOP & crew will not attempt ignition. Will Fault Isolate to CV8. May remove and replace CV8.
All Connections in-and-out of any components on gas line through N2 high pressure supply manifold.	To transfer N2 through the manifold.	FOMA-02-36	fails	1R	N2 leakage into cabin constitutes a hazard. Worst case- The N2 could fill part of the cabin forming a oxygen depleted zone.	Hazardous to crew. Detection of leak may necessitate system shutdown. Non-detection of leak may result in oxygen depletion threat in the worst case. Inability to perform experiments.	TBD	Leaks in components caused by faulty seals, imperfect mating, or damaged connections.	Leaks in components caused by faulty seals, imperfect mating, or damaged connections. All pressure transducer outputs would be monitored. Strict attention to pressure profile curves and pressure readings in combustion chamber. TE = TDB TD = TBD	In the event that instrumentation indicates conditions which could be the result of system leakage, the fill procedure will be terminated and off-nominal procedure implemented. This could consist of closing the external GN2 manual valve and power shutdown to FOMA. Pressure decay leak check. Fault Isolate to manifold. Remove and replace manifold.
PR 4 Pressure Regulator	Regulate N2 gas pressure.	FOMA-02- 37	fails	1R	Loss of N2 gas needed for experiments. Hazard to crew: oxygen depletion threat.	Incorrect test conditions due to incorrect gas flow. Ignition would provide incorrect experiment and data not useful.	TBD	Broken seals , cracked seals caused by inherent weakness. Sensitivity to environment.	PT 11 and 12 would indicate high pressure. A hand held monitor will also be used. TE = TDB TD = TBD	Shutdown manifold. Remove faulty PR 4 and replace with spare.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
Solenoid Valve SV 28	Flow control for auxiliary high pressure line. (line to combustion chamber which by-passes pressure regulator)	FOMA-02-38	fails	2R	Does NOT allow N2 to flow through auxiliary high pressure line.	Cannot provide high pressure N2 for high pressure experiments. May continue with other experiments utilizing the normal N2 gas line.	TBD	Coil Burn out. (may be caused by premature wear of coil)	PT 28 and 29 would indicate lower pressure than expected. TE = TDB TD = TBD	Shutdown power to manifold. Fault Isolation would be performed to SV 28. Would remove SV 28 and replace with a spare.
Solenoid Valve SV 28	Flow control for auxiliary high pressure line. (line to combustion chamber which by-passes pressure regulator)	FOMA-02-39	fails	1R	Allows additional N2 to flow through auxiliary high pressure line.	Could allow unlimited N2 flow into combustion chamber if condition is not detected and SV20 does not shutdown flow.	TBD	Large Debris or excessive contamination on seat.	PT 28 and 29 would indicate higher pressure than expected. TE = TDB TD = TBD	Send closure signal to SV20. Shutdown power to manifold. Complete Off-nominal procedure for this situation.
Quick Disconnect: GN2 supply from space station	Transfer of N2	FOMA-02-40	fails	1R	N2 leakage into cabin constitutes a hazard. Worst case- The N2 could fill the cabin forming a oxygen depleted zone.	Detection of leak may necessitate system shutdown. Non-detection of leak may result in oxygen depletion threat in the worst case. Inability to perform experiments	TBD	Corrosion, pre-mature wear. Galling	In the more severe case, Pressure transducers may show loss of pressure. In less severe cases (small leak) this failure may go undetected. TE = TDB TD = TBD	Replacement of the Quick disconnect may be required.
GN2 Supply Manual valve	Manual control of N2 flow out of space station supply	FOMA-02-41	fails	1S	Inability to manually shut down N2 flow at Source point.	Inability to shut down N2 input flow at the source in the event of an emergency.	TBD	Corrosion, pre-mature wear. Galling	Pressure transducers would read no reduction in line pressure TE = TDB TD = TBD	Space station crew/computers would have to shut down N2 flow upstream of the manual valve.

Item	Function	Failure mode No.	Failure Mode	Crit.	Local Effe ct	System Effect	Station/Crew Effects	Potential Causes	Detection Method/Time to Effect = TE, Time to Detect = TD	Compensating Provision
Quick Disconnect: GN2 supply from space station	Transfer of N2	FOMA-02-42	fails	3	Cannot disconnect from Station N2 supply line	Cannot disconnect from Station N2 supply line	TBD	Damage to QD by vibration	Visual TE = TDB TD = TBD	TBD

TABLE III. FMEA WORKSHEET FOR THE FOMA Diluent Gas Supply Manifold

*****MIL-STD-1522A test requirement modified as per NSTS 1700.7B paragraph 208.4.

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03	Diluent Supply									
FOMA-03-1	GB3 Gas Bottle	Storage of diluent / premixed gas	Burst (rupture of cylinder)	1	Loss of diluent pre-mixed gas. Possible damage to surrounding FOMA.	Loss of test points requiring GB3. Hazard to crew: Release of flammable and/or toxic gas. Possible ejection of projectiles.	TBD	Structural Failure. Stress cracking due to pressure loads, launch environment, or thermal gradients.	Visual, immediate effects. (This structural failure is intolerable and must be avoided.)	GB2 designed for: LBB, tested as per MIL-STD 1522A* with positive margin of safety on burst/MDP and FS requirements. Proof tests.
FOMA-03-2	GB3 Gas Bottle	Storage of diluent / premixed gas	Leakage	1R	Loss of diluent pre-mixed gas.	Hazard to crew: Release of flammable and/or toxic gas.		See above	See Above	
FOMA-03-3	MV3 Manual Valve	Manual control of gas flow out from GB3	Valve fails open. (stuck in open position)	1R	Inability to manually cut-off flow from GB-3	Inability to manually shut off supply from GB3 in an emergency	TBD	Corrosion or Contamination.	Pressure Transducers show pressure increase.	Fuel can be diluted in chamber and vented prior to bottle removal.
FOMA-03-4	MV3 Manual Valve	Manual control of gas flow out from GB3	Valve fails closed. (stuck in closed position)	1 R	Inability to manually turn on supply from GB3	Loss of ability to provide gas supply from GB3 to Chamber. Loss of certain test points.	TBD	Contamination and Corrosion.	Transducers show no/little pressure	Remove GB3 and replace with new bottle.

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03-5	MV3 Manual Valve	Manual control of gas flow out from GB3	Valve Leakage	1R	Loss of diluent or premixed gas from GB3.	Loss of test points requiring GB3 supply. Hazard to crew: Release of flammable and/or toxic gas in oxygen .	TBD	Contamination, Corrosion, or galling.	Transducers show no/little pressure	Shut down fill operation. The amount of gas in the bottle is limited to prevent the rack atmosphere from reaching an unsafe percentage of LEL and from reaching SMAC levels.
FOMA-03-6	GB2 Gas bottle	Storage of diluent / premixed gas	Provides contaminated supply	2R	Contaminated diluent or premixed gas may be passed on to chamber	Faulty scientific data as a result of burns containing contaminants	TBD	Gas storage bottle did not meet contamination control requirements.	Faulty scientific data.	F3 Provides Filtering of diluent or premixed gas carried in line.
FOMA-03-7	QD3 Quick disconnect	Transfer of diluent / premixed gas	Fails to allow safe/correct connection	2R	Inability to provide diluent / premixed gas for experiments	Loss of Test points.	TBD	Corrosion, premature wear, galling.	Visual and immediate effect.	Maintenance /replacement of quick disconnect required.
FOMA-03-8	PI3 Pressure Indicator	Indicates pressure in order to give crew an indication that gas bottle can be removed.	Reads a pressure that is lower than actual	1R	Provides incorrect data to to crew	May not be able to disconnect bottle. Disconnection could propel bottle away from quick disconnect.	TBD	Spring performance incorrect.	PT7 Trans-ducer reading relayed to crew by computer. Comparison with PI reading.	Comparison with PT7 pressure transducer would provide a monitoring of bottle pressure. Would indicate if bottle can be safely removed.
FOMA-03-9	PI3 Pressure Indicator	Indicates pressure in order to give crew an indication that gas bottle can be removed.	Reads a pressure that is higher than actual	3	Provides incorrec t data to the crew	Timing of bottle change out will be questioned.	TBD	Spring performance incorrect.	PT7 Transducer reading relayed to crew by computer. Comparison with PI3.	Transducer would indicate true pressure. Crew would be informed that it is safe to remove the bottle.

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03-10	PI3 Pressure Indicator	Indicates pressure in order to give crew an indication that gas bottle can be removed.	Fails to operate. No reading.	1R	Provides NO data to crew	May not be able to disconnect bottle. Disconnection could propel bottle away from quick disconnect.	TBD	Loss of signal.	PT7 Transducer reading relayed to crew by computer. Comparison with PI3 reading.	Comparison with PT7 pressure transducer would provide a monitoring of bottle pressure. Would indicate if bottle can be safely removed.
FOMA-03-11	PT7 Pressure Transducer	Provides an exact measurement of pressure	Reads a pressure that is lower than actual	1R	Provides incorrect data to computer and/or crew	Could conceivably allow build up of pressure on line without crew knowledge. Possible Hazard.	TBD	Leaking, loss of signal, performance drifts out of spec.	Data from other Pressure transducers on the line would contradict PT7.	PT7 has back-up from the regulator set at 95 psi., pressure switch set at 97 psi., and the pressure transducer/computer-solenoid at 99 psi.
FOMA-03-12.	PT7 Pressure Transducer	Provides an exact measurement of pressure	Reads a pressure that is higher than actual	2R	Provides incorrect data to computer and/or crew	Could conceivably cause computer to shut down gas supply and lose some test points.	TBD	Performance drifts out of specification.	Data from other Pressure transducers on the line would contradict PT4.	Would need a procedure to re-open valves and clear erroneous data from computer to re-start fill operation.
FOMA-03-13.	PT7 Pressure Transducer	Provides an exact measurement of pressure	Fails to operate. No reading.	1R	Provides NO data to computer and/or crew.	Gas pressure in line could build up without crew knowledge. Possible Hazard.	TBD	Loss of signal. May be caused by open-circuit failure.	Data from other Pressure transducers on the line would contradict PT7.	PT7 has back-up from the regulator set at 95 psi., pressure switch set at 97 psi., and the pressure transducer/computer-solenoid at 99 psi.

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03-14.	F3 Filter	Provides Filtering of gas carried in line	Fails to stop contaminants	3	Contaminants are passed on through the line.	Faulty data: Burns containing contaminants	TBD	Holes, damage, or deterioration	Faulty data may result in detection	Filter is replaceable. Exhaust, clean, vent, re-fill with spare bottle
FOMA-03-15.	F3 Filter	Provides Filtering of gas transferred through line	Fails to stop some contaminants	3	Contaminants are passed on through the line in small amounts.	Some inaccuracy in scientific data as a result of burns containing small contaminants	TBD	Partial damage	"Skewed" data or inaccuracies may initiate trouble-shooting	Filter is replaceable. Exhaust, clean, vent, and re-fill with spare gas bottle.
FOMA-03-16.	F3 Filter	Provides Filtering of gas transferred through line	Clogged	3	Stops or greatly reduces gas flow to mass-flow controller	Could affect fill time for combustion chamber	TBD	Large size contamination and/or debris inside filter	Troubleshooting proced-ure for FOMA-03	Filter is replaceable.
FOMA-03-17	SV10,9, or 17 Solenoid Valves	Control of gas flow (pressure)	Fails to open	2R	Inability to provide diluent / premixed gas for experiments	Loss of test points.	TBD	Coil Burn out. (may be caused by premature wear of coil)	Current draw feedback monitored by computer, pressure transducers indication downstream.	Design of Solenoid Valves is maintainable: Defective coils can be removed and replaced with spare coil.
FOMA-03-18	SV10,9, or 17 Solenoid Valve	Control of gas flow (pressure)	Fails to close completely	1R	Allows gas flow to reduced level when shut down is intended	Could be a contributing cause to a hazard.	TBD	Large Debris or excessive contamination on seat	Pressure transducers indication dow nstream.	Design of Solenoid Valves is maintainable: If valve will not close due to failure, entire valve can be re-moved and replaced.

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03-19	SV10,9, or 17 Solenoid Valve	Control of gas flow (pressure)	Leakage to environment	1R Note: If a leak is confirmed, experiment would be shut down and Leak checks would be performed.	Inability to provide diluent / premixed gas for experiments. Hazard to crew: flammability/toxic substance threat.	Detection of leak may necessitate system shutdown. Non-detection of leak may result in a flammability hazard or toxic substance threat.	TBD	Broken seals, cracked seals, caused by inherent design weakness like sensitivity to changes in temperature or vibration.	Pressure transducers downstream like PT 15,28, and 29 would indicate low pressure	Design of Solenoid Valves is maintainable: If valve is leaking, due to seal failure, entire valve can be removed and replaced. Bottle size and amount of gas are selected to avoid flammability/toxic concerns.
FOMA-03-20	PR3 Pressure Regulator	Regulate diluent / premixed gas pressure from 2000 PSI to 100 PSI.	Fails to regulate pressure down to specified 100 PSI.	1R	Buildup of pressure in gas line. Possible over-pressurization	Detection of over-pressure condition by pressure switch will shut solenoid valves on line.	TBD	loss of initial setting. Loose internal parts from launch vibe.	PT 8, and 9 would measure over pressure.	Any pressure over specified amount for experiment and all solenoids shut. Pressure regulator can be replaced.
FOMA-03-21	PR3 Pressure Regulator	Regulate diluent / premixed gas pressure from 2000 PSI to 100 PSI.	Over-regulates pressure far below 100 PSI.	3	Reduction of flow rate to mass flow controller.	Possible loss or delay of some test points.	TBD	loss of initial setting. Loose internal parts from launch vibe.	PT 8, and 9 would measure low pressure.	Re-set pressure regulator. Second failure may necessitate removal and replacement.

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03-22	PT 26 Pressure Transducer	Provides an exact measurement of pressure across the diaphragm. Used to detect diaphragm rupture.	Reads a pressure that is lower than actual	2R	Provides incorrect data to computer and/or crew	Inability to detect rupture of pressure regulator diaphragm.	TBD	Leaking, loss of signal, performance drifts out of spec.	Data from other Pressure transducers on the line would contradict PT26.	PT26 reading a lower pressure would indicate a detection failure of the pressure transducer and this item would be replaced.
FOMA-03-23	PT26 Pressure Transducer	Provides an exact measurement of pressure across the diaphragm. Used to detect diaphragm pressure.	Reads a pressure that is higher than actual	2R	Provides incorrect data to computer and/or crew.	Could conceivably cause computer to command solenoid valves to close and shut off gas supply.	TBD	Leaking, loss of signal, performance drifts out of spec.	Data from other Pressure transducers on the line would contradict PT26.	Would replace PT 26. If problem persisted, then PR 3 would be replaced.
FOMA-03-24	PT26 Pressure Transducer	Provides an exact measurement of pressure across the diaphragm. Used to detect diaphragm rupture.	Fails to operate. No reading.	2R	Provides NO data to computer and/or crew.	Inability to detect rupture of pressure regulator diaphragm.	TBD	Leaking, loss of signal, performance drifts out of spec. May be caused by open-circuit failure.	Data from other Pressure transducers on the line would contradict PT26.	Would need a procedure to re-place PT26. Re-open valves and clear erroneous data from IOP to re-start fill operation.
FOMA-03-25	PS3 Pressure Switch	Would provide computer the capability to shut solenoid valves if pressure downstream of PR3 exceeds 100 PSI.	Fails to switch solenoid valves on the line to closed position.	1R	Buildup of pressure in gas line. Possible over-pressurization. Reliance now on PT8 to shut solenoid valves.	May allow gas pressure on line to build up and presents a hazard in the event of PT 8 failure. Threat of possible over-pressurization.	TBD	Leaking, loss of signal, performance drifts out of spec.	Data from Pressure transducers on the line would indicate loss of pressure control.	Would need a procedure to re-place PS3. Re-open valves and clear erroneous data from IOP to re-start fill operation

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03-26	PT8, PT9 Pressure Transducers	Provides an exact measurement of pressure	Reads a pressure that is lower than actual	1R	Provides incorrect data to computer and/or crew	Could conceivably allow build up of pressure on line without crew knowledge. Possible Hazard	TBD	Leaking, loss of signal, performance drifts out of spec.	PT 15, 28, & 29 readings will not be consistent with PT 8 & 9.	Would need a procedure to re-place PT8 & 9. Re-open valves and clear erroneous data from IOP to re-start fill operation
FOMA-03-27	PT8,PT9 Pressure Transducers	Provides an exact measurement of pressure	Reads a pressure that is higher than actual	2R	Provides incorrect data to computer and/or crew	Could conceivably cause computer to command solenoid valves to close and shut off gas supply.	TBD	Leaking, loss of signal, performance drifts out of spec.	PT 15, 28, & 29 readings will not be consistent with PT 8 & 9.	Would need a procedure to re-place PT8 & 9. Re-open valves and clear erroneous data from IOP to re-start fill operation
FOMA-03-28	PT8, PT9 Pressure Transducers	Provides an exact measurement of pressure	Fails to operate. No reading.	1R	Provides NO data to computer and/or crew.	Gas pressure in line could build up without crew knowledge	TBD	loss of signal caused by open-circuit failure.	PT 15, 28, & 29 readings will not be consistent with PT 8 & 9.	Would need a procedure to re-place I/O card in the FCU and/or PT8 & 9. Re-open valves and clear erroneous data from IOP to re-start fill operation

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03-29	MFC2: Mass flow controller	Meters mass flow of diluent /premixed gas to combustion chamber for experiments	Allows too much flow	1R	Flow output is greater than set-point. Control valve tries to close.	Incorrect test conditions due to incorrect gas flow. Mass of flammable gas in chamber may exceed requirement for test point. Possible over pressurization presents a hazard.	TBD	1.Internal control valve coil does not electrically respond or does not respond correctly to closure signal. 2.Internal valve has corrosion or contamination.	PT 15, 28, & 29 readings will indicate rapid build-up of pressure.	Timers will provide closure signal to SV7 & 8.Fuel-to-oxygen mixture ratio will be checked. IOP & crew will not enable ignition. Fault Isolate to MFC2 and replace MFC2.
FOMA-03-30	MFC2: Mass flow controller	Meters mass flow of diluent /premixed gas to combustion chamber for experiments	Allows too little flow	3	Flow output is less than set point. Control valve tries to open.	Incorrect test conditions due to incorrect gas flow. Ignition would provide incorrect experiment and data not useful.	TBD	Internal solenoid will not open or will not open completely, due to a burned out or damaged coil.	PT 15, 28, & 29 readings will indicate pressure is too low.	Fuel-to-oxygen mixture ratio will be verified. IOP & crew will not enable ignition. Fault Isolate to MFC2 and replace MFC2.
FOMA-03-31	MFC2: Mass flow controller	Meters mass flow of fuel/pre-mixed gas to combustion chamber for experiments	Reads mass flow as higher than actual	3	Principle Investigator stationed on ground, may not notice that values are too high.	Could lead to incorrect measure-ment of the total mass involved in experiment. PI would get "skewed" scientific results.	TBD	MFC calibrated incorrectly, or not calibrated. MFC output drifts out of specification. MFC damaged by launch vibe.	PT 15, 28, & 29 readings will indicate expected pressure in line and will not agree with MFC2.	Fuel-to-oxygen mixture ratio will be verified. IOP & crew will not enable ignition. Fault Isolate to MFC2 . Re-calibrate MFC2 or remove and replace MFC2.
FOMA-03-32	MFC2: Mass flow controller	Meters mass flow of diluent /premixed gas to combustion chamber for experiments	Reads mass flow as lower than actual	3	Principle Investigator stationed on ground, may not notice that values are too low.	Could lead to incorrect measure-ment of the total mass involved in experiment. PI would get "skewed" scientific results.	TBD	MFC calibrated incorrectly, or not calibrated. MFC output drifts out of specification. MFC damaged by launch vibe.	PT 15, 28, & 29 readings will indicate pressure expected pressure and will not agree with MFC1.	IOP & crew will not enable ignition. Fault Isolate to manifold. Re-calibrate MFC1 or remove and replace manifold.

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03-33	MFC2: Mass flow controller	Meters mass flow of diluent /premixed gas to combustion chamber for experiments	Allows NO flow-through of fuel or pre-mixed fuel.	3	PT 15, 26, and 27 read low pressure.	Unable to perform experiment with contents of GB3. Cannot start ignition. Nothing to burn.	TBD	Internal solenoid will not open due to a burned out or damaged coil.	Pressure transducers upstream of MFC2 read positive pressure but readings downstream show little or no pressure.	IOP & crew will not attempt ignition. Will Fault Isolate to manifold. Remove MFC2 or remove and replace manifold.
FOMA-03-34	All Connections in-and-out of any components on gas line through manifold.	To transfer diluent / premixed gas through the manifold.	Leakage into combustion integrated rack	1R	Diffusion and spreading of flammable and/or possibly toxic gas.	Hazardous to crew. Possible fire hazard.	TBD	Leaks in components caused by faulty seals, imperfect mating, or damaged connections.	All pressure transducer outputs would be monitored. Strict attention to pressure profile curves and pressure readings in combustion chamber.	In the event that instrumentation indicates conditions which could be the result of system leakage, the fill procedure will be terminated and off-nominal procedure implemented. Pressure decay leak check. Isolate to manifold. Remove and replace manifold. Bottle sizes and content pressures are selected to assure all LFL and SMAC levels are met in the case of leakage into the rack.

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03- 35	PR 3 Pressure Regulator	Regulate diluent / premixed gas pressure from 2000 PSI to 100 PSI.	Diaphragm Rupture	1	Loss of diluent / premixed gas needed for experiments. Hazard to crew: flammability/toxic substance threat.	Detection of leak may necessitate system shutdown. Non-detection of leak may result in a flammability hazard or toxic substance threat.	TBD	Broken seals or cracked seals caused by inherent design weakness like sensitivity to changes in temperature or vibration.	PT 26 would indicate pressure.	Design of pressure regulator is maintainable: If regulator is leaking due to seal failure, entire regulator can be removed and replaced. Bottle size and amount of gas are selected to avoid flammability/ toxic substance concerns.
FOMA-03-41	QD2 quick disconnect	Transfer of diluent /premixed gas	Leakage	1R	Loss of diluent / premixed gas supply.	Loss of test points requiring GB3 supply. Hazard to crew: Release of flammable and/or toxic gas in oxygen	TBD	Corrosion, pre-mature wear. Galling	In the more severe case, Pressure transducers may show loss of pressure. In less severe cases (small leak) this failure may go undetected.	Replacement of the Quick disconnect may be required.
FOMA-03-42	QD2 quick disconnect	Transfer of diluent /premixed Gas	Difficult or unable to dis-engage QD	3	Unable to dis-connect diluent/ premixed supply line from gas bottle GB3.	Unable to change diluent/ premixed supply for next experiment.	TBD	Damage to QD From vibration.	Visual	Would have to switch over to use of N2 line to perform experiments that could be accomplished until problkem with GB3 is corrected.

Package and Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station /Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-03-43	CV6 check valve	Isolates Diluent Premixed gas Supply manifold	Leakage (external)	1R	Leakage of diluent gases into CIR	Could constitute a toxicity threat or flammability hazard.	TBD	Damage to valve.	TBD.	TBD.
FOMA-03-44	CV6 check valve	Isolates Diluent Premixed gas Supply manifold	Fails to close when required	2R	Loss of pro-tection from back-flushing effect.	May necessitate shutdown of diluent manifold. Switch over to use of nitrogen supply manifold.	TBD	Contamination or corrosion.	TBD.	TBD.
FOMA-03-45	CV6 check valve	Isolates Diluent Premixed gas Supply manifold	Fails to open	2R	Cannot flow diluent into Combustion chamber	Forced to either fault isolate or switch over to use of nitrogen supply manifold.	TBD.	Contamination or corrosion.	TBD.	TBD.
FOMA-03-46	Filter F3	Filters debris from gas line	Leakage	3	Leakage of diluent gases into CIR	toxicity threat or flammability hazard.	TBD.	TBD.	TBD.	TBD.

TABLE IV. FMEA WORKSHEET FOR THE FOMA High Percentage Oxygen Supply Manifold

*MIL-STD-1522A test requirement modified as per NSTS 1700.7B paragraph 208.4.

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-04	High Percentage Oxygen supply Manifold.									
FOMA-04-1	GB-1 Oxygen Supply Bottle	Provide O2 for Combustion	Burst	1	Loss of O2 supply, possible damage to local components.	Loss of test points, Fire hazard, ejection of Projectiles.	TBD	Structural failure due to crack growth under applied stresses.	Visual and immediate effect.	Design GB1 as LBB. Qualify per MIL-STD-1522A. *
FOMA-04-2	GB-1 Oxygen Supply Bottle	Provide O2 for Combustion	Leakage	1R	Loss of O2 supply.	Loss of test points, Fire hazard.	TBD	Crack growth to Surface creating a small hole	Transducers read low pressure.	Design GB1 as LBB. Qualify to MIL-STD-1522A.*
FOMA-04-3	GB-1 Oxygen Supply Bottle	Provide O2 for Combustion	Provides Contaminated O2	2R	Contaminants passed to chamber	Faulty or skewed science data.	TBD	Failure to meet Contamination control requirements	None. After experiment Scientific data is skewed.	Filter F1 provides filtering of O2 Supply.
FOMA-04-7	QD1 Quick disconnect	Provide connection of Bottle supply to line for O2 transfer	Fails to allow safe/correct connection	3	Cannot permit flow of O2.	Loss of ability to provide O2 to Chamber. Cannot perform tests.	TBD	Contamination, Corrosion, premature wear or galling.	Astronauts unable to correctly attach gas bottle to line.	Must be able to remove failed QD and replace it.
FOMA-04-8			Leakage	1R	Loss of O2 needed for experiment.	Release of O2 into CIR. Fire Hazard. Loss of O2 needed for experiments.	TBD	Vibration levels Cause damage to QD.	Transducers show no/little pressure.	TBD

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-04-8A			Difficult or unable to disengage	3	Unable to disconnect gas bottle	Unable to operate manifold for successive experiments	TBD	Same as above	Visual	TBD
FOMA-04-9	PI1 Pressure Indicator	Indicates Pressure in order to give the crew an indication that the gas bottle can be removed.	Reads a pressure that is higher than actual	3	Provides incorrect data to the crew.	Timing of bottle change out will be questioned.	TBD	Spring performance incorrect.	PT1 Transducer reading relayed to crew by computer. Comparison with PI1.	Other Transducers would indicate true pressure. Crew would be informed that it is safe to remove the gas bottle.
FOMA-04-10			Reads a pressure that is lower than actual.	1R	Provides incorrect data to the crew.	May not be able to disconnect bottle. Disconnection could propel bottle away from QD1.	TBD	Spring performance incorrect.	(Same as above)	(Same as above)
FOMA-04-11			Fails to operate. No reading.	1R	Provides no data to the crew.	May not be able to disconnect bottle. Disconnection could propel bottle away from QD1.	TBD	Spring performance incorrect.	PT1 Transducer reading relayed to crew by computer. Comparison with PI1.	Other Transducers would indicate true pressure. Crew would be informed that it is safe to remove the gas bottle.
FOMA-04-12	PT1, 2, 3, & 18 Pressure Transducers	Provides data on O2 line pressure to crew	Reads a pressure that is higher than actual.	2R	Provides incorrect data to computer and/or Crew	Could cause the gas supply to be shut down and stop fill operation.	TBD	Performance drifts out of spec.	Data from other pressure transducers on the line would contradict transducer.	Would need a procedure to re-open valves and clear erroneous data from computer to re-start fill operation. PT may have to be removed and replaced.

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-04-13			Reads a pressure that is lower than Actual.	1R	Provides incorrect data to computer and/or Crew	In the event that O2 pressure was building up in the line, the crew would have incorrect information.	TBD	Loss of signal, Performance of PT is drifting out of spec.	Data from other pressure transducers on the line would contradict Transducer.	Failure tolerance from over-pressurization is designed in. PT has back-up from the pressure regulator and pressure switch.
FOMA-04-14			Fails to operate. No Reading.	1R	Provides No data to comput er and/or crew.	In the event that O2 pressure was building up in the line, the crew would have No information from PT.	TBD	Loss of signal, Performance of PT is drifting out of spec.	Data from other pressure transducers on the line would be Provided.	(See above)
FOMA-04-15	F1 Filter	Provide filtering of O2 carried in gas line	Fails to stop contaminants	3	Contaminants are passed on through the line.	Faulty data: Burns containing contaminates.	TBD	Holes, damage/ deterioration.	Faulty data may result in detection of Problem.	Filter can be replaced. Exhaust, clean, vent and re-fill with spare bottle.
FOMA-04-16			Fails to stop some contaminants.	3	Small amounts of contaminants are passed on through the line.	Some inaccuracy in science data as a result.	TBD	Holes, damage/ deterioration.	Pressure transducers in the line will indicate lower pressure.	Filter can be replaced. Exhaust, clean, vent and re-fill with spare bottle.
FOMA-04-17			Clogged	3	Stops or greatly reduces O2 flow to mass flow controller.	Cuts off O2 supply to chamber and experiment cannot be performed.	TBD	Large size particles and/or debris in filter blocks gas flow out.	(See above)	(see above)

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effe ct	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensatin g Provision
FOMA-04-17a			Leakage	1R	Release of O2 (prior to pressure regulator) into CIR.	Fire Hazard. Loss of O2 needed for experiments.	TBD	Cracked or damaged filter.		
FOMA-04-18	Solenoid valves SV 3,4, and 5.	Control of Gas flow.	Leakage	1R	Loss of O2 from supply. O2 will diffuse into CIR.	Fire hazard. Loss of O2 needed for Experiment		Seal failure.	Transducer s show reduced pressure.	Shut down O2 supply at MV1. Allow O2 in CIR to safely dissipate. Safely remove O2 from combustion chamber. Removal & replacement of defective Solenoid valve.
FOMA-04-19			Fails to open.	2R	Blocks flow of O2 through line.	Cannot provide O2 supply for Combustion experiment.		Coil burn out.	Pressure transducers upstream of solenoid valve would show pressure but transducers downstrea m would read reduced pressure.	Shut down O2 supply at MV1. Safely remove O2 from combustion chamber. Removal & replacement of defective Solenoid valve..
FOMA-04-20			Fails to Close completely.	1R	Allows flow of O2 when shut down is intended.	Possible contributing cause to a hazard.		Large debris or excessive contamination on valve seat.	Pressure transducer indication downstrea m.	See above.

Failure mode No.	**Item**	**Function**	**Failure Mode**	**Crit**	**Local Effect**	System Effect	**Station/Crew Effects**	**Potential Causes**	**Detection Method**	**Compensating Provision**
FOMA-04-21	PR1 Pressure Regulator	Regulates the input pressure from 2000 psi down to specified pressure.	Fails to regulate pressure down to specified level.	1R	Buildup of pressure in gas line. Possible over-pressurization.	Detection of over-pressure condition by pressure switch will shut solenoid valves on line.	TBD	Loss of initial setting. Loose internal parts/damage from launch vibe.	PT2 Transducer reading relayed to crew by computer. Comparison with PI1.	Any pressure over specified amount for experiment and all solenoids shut. Pressure regulator can be replaced.
FOMA-04-22			Over-regulates pressure far below specified level.	3	Reduction of flow rate to mass flow controller	Possible loss or delay of some test points.	TBD	Loss of initial setting. Loose internal parts/damage from launch vibe.	PT2 Transducer reading relayed to crew by computer. Comparison with PI1.	May have to remove failed pressure regulator and replace it.
FOMA-04-23	PR1 Pressure Regulator	Regulates the input pressure from 2000 psi down to specified pressure.	Leakage	1R	Leakage of O2 leading to loss of O2 needed for experiment	Leakage of O2 into CIR. Possible fire hazard.	TBD	1.Seat damage due to chemical reaction or debris. 2. Diaphragm failure.	PT2 Transducer reading relayed to crew by computer. Comparison with PI1 reading.	Comparison with PT1, PT2 pressure transducers would provide a monitoring of input pressure. Would tend to indicate leakage. Pressure regulator tends to be robust component.
FOMA-04-24	PS1 Pressure Switch	Provides capability to shut solenoid valves if pressure downstream of PT1 exceeds 100 psi.	Fails to switch solenoid valves to closed position.	1R	Buildup of O2 pressure in gas line. Reliance now on PT2 to shut solenoid valves.	Possible threat of over-pressurization in the event of other failures.	TBD	Broken internal spring.	Data from transducers would indicate pressure build-up.	Pressure switch is backed up by pressure regulator and PT/computer system.

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-04-25.	MFC3 Mass Flow controller	Meters flow of oxygen to combustion chamber for experiments	Allows flow that is higher than required.(too much flow)	1R	Flow output is greater than set point. Control valve tries to close.	Incorrect test conditions due to incorrect flow of O2. Possible over-pressurization of chamber during combustion. Possible Hazard.	TBD	Internal control valve is stuck in open position. Control valve does not respond. Sensor tubes faulty and cause MFC to go full open.	PT 15, 28, &29 readings would indicate a buildup of pressure.	Timers will provide closure signal to SV4 and SV5. Fuel-to-Oxygen ratio will be checked prior to ignition. Can remove and replace MFC3.
FOMA-04-26			Allows flow that is lower than required. (too little flow)	2R	Flow output is less than set-point. Control valve tries to open.	Incorrect test conditions due to incorrect flow of O2. Ignition would provide incorrect experiment and data.	TBD	Internal solenoid may not open completely if coil is damaged or burned out.	PT 15, 28, &29 readings would indicate a loss of pressure.	Fuel-to-oxygen mixture ratio will be verified. IOP and crew will not enable ignition. Would Fault isolate to MFC3. Remove and replace MFC3.
FOMA-04-27			Reads mass flow as higher than actual .	2R	Principle Investigator on ground may not notice that values are too high.	Could lead to incorrect measurement of the total O2 mass involved in the experiment. PI would get “skewed” scientific results.	TBD	MFC calibrated incorrectly, or not calibrated. MFC output drifts out of spec. MFC damaged by launch vibe.	PT 25, 28, and 29 readings will indicate expected pressure in line and will not “agree” with MFC3.	Fuel-to-oxygen mixture ratio will be verified. IOP and crew will not enable ignition. Would Fault isolate to MFC3. Recal-ibrate MFC3, or remove and replace MFC3.

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-04-28.			Reads mass-flow as lower than actual.	2R	Principle Investigator on ground may not notice that values are too low.	Could lead to incorrect measurement of the total O2 mass involved in the experiment. PI would get "skewed" scientific results.	TBD	MFC calibrated incorrectly, or not calibrated. MFC output drifts out of spec. MFC damaged by launch vibe.	PT 25, 28, and 29 readings will indicate expected pressure in line and will not "agree" with MFC3.	Fuel-to-oxygen mixture ratio will be verified. IOP and crew will not enable ignition. Would Fault isolate to MFC3. Recal-ibrate MFC3, or remove and replace MFC3.
FOMA-04-29			Allows no flow through of O2.	2R	PT 25, 26, and 27 read low pressure.	Unable to perform experiment with contents of GB3. (If ignition was attempted, a mixture with some O2 might actually burn but results would be unsatisfactory)	TBD	Internal solenoid valve fails in closed position or MFC is clogged. Internal "sensor system " of MFC might mal-function and shut flow control valve way down.	Pressure transducers upstream of MFC3 read positive but readings downstrea m show little or no pressure.	Fuel-to-oxygen mixture ratio will be verified. IOP and crew will not enable ignition. Would Fault isolate to MFC3. Recal-ibrate MFC3, or remove and replace MFC3.
FOMA-04-35	CV7 Check valve	Prevents any gases from other manifolds from back-flushing into the O2 supply Manifold.	Fails to close when required to close.	2R	Loss of protection from back-flushing	Build-up of pressure would be detected. Would force a shutdown.	TBD	Internal mechanical or electrical failure	Pressure transducers PT 9 and 15 would show gradient into 02 manifold.	IOP and crew will not give command for ignition. Will fault isolate and confirm CV7 failure.

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
			Fails to open when required to open.	2R	Cannot flow O2 Into combustion chamber	Inability to carry out experiment.	TBD	Debris or contamination on seat.	Pressure transducers PT 9 and 15 would show low pressure downstream from CV7.	IOP and crew will not give command for ignition. Will fault isolate and confirm CV7 failure.
			Leakage	1R	O2 leakage into CIR.	Possible Fire Hazard. Loss of oxygen needed for Experiment.	TBD	Cracked seal or valve damage.	PT 15 would start to show a loss of line pressure.	IOP and crew will not give command for ignition. Will fault isolate and confirm CV7 failure.
FOMA-04-36	MV1 Manual Bottle valve	Allows O2 to flow from bottle into the manifold line.	Valve stuck open	1S	Cannot manually shut off O2 flow from bottle.	Cannot shut off O2 flow from the source in the event of an emergency.	TBD	Damaged valve internally.	Pressure rise PT1 and no reduction in pressure after turning MV1.	TBD
FOMA-04-37			Valve stuck closed	2R	Cannot enable flow of O2 from Source.	Cannot initiate fill of chamber with required O2. Will most likely be caught by GC sampling. If not, burn could proceed without enough O2. Experimental data would be defective.		Contamination or corrosion.	No increase in pressure measured by PT1 after turning MV1.	TBD

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-04-38			Leakage	1R	Leakage of O2 into CIR.	Loss of O2 needed for experiment. Leakage of O2 presents a fire hazard.		Cracked seal or valve damage.	Smaller than Expected increase in pressure measured by PT1 after turning MV1.	TBD

TABLE V. FMEA WORKSHEET FOR THE FOMA Static Mixer

*****MIL-STD-1522A test requirement modified as per NSTS 1700.7B paragraph 208.4.

Failure mode No.	**Item**	**Function**	**Failure Mode**	**Crit**	**Local Effect**	System Effect	**Station/Crew Effects**	**Potential Causes**	**Detection Method**	**Compensating Provision**
FOMA-05-1	Static Mixer Stainless Steel Multi-helical tubing No moving parts. No electrical interface. Orifice size rules out clogging as a viable failure mode.	In "Static" operating mode will transfer the content of one gas bottle at a time to combustion chamber. In dynamic mixing mode, will accept input from 2 or 3 gas manifolds at one time and force all gases to mix.	Leakage	1R	Leakage of various gases such as Premixed Fuels, Oxygen and/or Nitrogen into CIR.	Release of gases into CIR constitutes Hazard for Fire or oxygen depletion in the worst case. Gases needed for experiment are lost. Experiment burn would not contain appropriate amounts of fuel and/or oxygen and would provide incorrect data.	All TBD	Structural weakness of static mixer. Crack growth from launch vibration. Fittings on static mixer are Defective and leak.	PT 15, 28, and 29 would read lower pressure than expected. Would not be consistent with pressure transducer readings within manifolds. Indication would be that gas was being lost somewhere on static mixer line.	Static Mixer is designed to be composed of stainless steel and should be of sufficient structural strength. Unit should be qualified for flight to demonstrate ability to survive launch vibe.
FOMA-05-2	Solenoid Valve SV14	When closed provides isolation from Exhaust Vent Package,	Leakage	1R	Leakage of various gases such as Premixed Fuels, Oxygen and/or Nitrogen into CIR.	(See directly above in this column)		Defective seals, Cracked valve housing.	(See directly above in this column)	Valve will be qualified for Flight vibration levels.
FOMA-05-3		when open provides alternate path to dump pre-combustion gases to Exhaust Vent package.	Fails to Open	1S	Inability to provide alternate path for venting of pre-combustion gases as part of off-nominal procedures.	Could contribute to a hazard. There may be situations (such as possible over-pressurization in the gas line) in which failure to open SV14 cuts off ability to reduce line presure.		Solenoid coil fails and valve will not open. SV 14 is operational but does not receive a signal to open.	PT 15, 28, and 29 would read higher pressure than expected.	TBD

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-05-4			Fails to Close	2R	Provides undesired alternate path which allows pre-combustion gases to flow toward Exhaust Vent Package.	Loss of pre-mix Fuel /oxygen or Nitrogen flow rate. May adversely affect gas mixture ratios for experiment.		Debris or contamination on valve seat.	PT 15, 28, and 29 would read lower pressure than expected.	TBD
FOMA-05-5			Reads a pressure that is higher than actual	2R	Provides incorrect or misleading data.	Could halt experiment if other trans-ducers failed.		Electrical performance drifts out of spec.	Readings from PT 28, and 29 would contradict PT 15.	TBD
FOMA-05-6			Reads a pressure that is lower than actual	1R	Provides incorrect or misleading data.	Could mislead crew when pressure in line is building up.		Electrical performance drifts out of spec.	Readings from PT 28, and 29 would contradict PT 15.	TBD
FOMA-05-7	Pressure Transducer PT15	Measurement of gas pressure output from static mixer.	No output	1R	Provides NO data.	Provides no data when pressure in line is building up.		Open-circuit failure or short.	Fall back to readings from PT 28 and PT29	TBD
FOMA-05-8			Reads a temperature that is higher than actual.	2R	False indication of output temperature	Readings on other temper-ature sensors will not be consistent with TC4. In the worst case, if other temp. sensors read high, the experiment could be shut down.		TBD	Readings on other temper-ature sensors will not be consistent with TS6.	TBD

Failure mode No.	Item	Function	Failure Mode	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
FOMA-05-9	Thermocouple TC4	Measurement of gas output **temperature** from static mixer.	Reads a temperature that is lower than actual.	1R	False indication of output temperature	Readings on other temperature sensors will not be consistent with TS6. Worst case: Other temp. sensors read low and hazardous condition is not detected.		TBD	Readings on other temperature sensors will not be consistent with TS6.	TBD
FOMA-05-10			No output	1R	No indication of output temperature	No data will be received from TS6. Worst case: Other temp. sensors fail and hazardous condition is not detected.		TBD	No data will be received from TS6.	TBD

TABLE VI. FMEA WORKSHEET FOR THE FOMA

*MIL-STD-1522A test requirement modified as per NSTS 1700.7B paragraph 208.4.

Item	Function by Schematic ID	Failure Mode and number	Crit	Local Effect	System Effect	Station/Crew Effects	Potential Causes	Detection Method	Compensating Provision
Combustion chamber, Valves and sensors to Combustion chamber	The combustion chamber contains various mixtures of combustible gases and fuels and the actual combustion of these fuels. Various sensors provide monitoring data on temperature and pressure in the chamber or on gas input and output lines connecting to the combustion chamber.					ALL TBD			
Solenoid Valves	The solenoid valves open to allow the flow of gases into the combustion chamber and close to isolate the other sections of the FOMA from gas inside the combustion chamber. The combustion chamber solenoid valves listed below interface with design packages as follows: SV 16: Fuel/Premixed Fuel Supply Manifold SV18: Static Mixer SV20: Bypass line around Static Mixer for Nitrogen SV15: Gas Chromat-ograph Package SV19: Pump Manifold SV21: Exhaust Manifold	FOMA-06-01: Any one solenoid valve Fails in closed position. (Will not open)	2R	Pre-combustion gases cannot flow into combustion chamber or Post - combustion gases cannot be vented or sent to GC for analysis.	Significant Loss of functionality . SV: 16, 18, or 20 - Inability to fill combustion chamber with required premixed fuel gases, diluent, oxidizer, or Nitrogen. SV15: Cannot transfer gases to GC for analysis. SV 21: Cannot transfer gases to Exhaust Manifold from chamber. SV19: Cannot circulate gases back to combustion chamber from Pump Manifold.		Coil Burn out.	PT 16,17, 28, and 29 will yield pressure measurements (pressure profile curve with time) which shows chamber pressure does not rise to expected values after valves along the fill line are commanded to open. Will have to fault isolate to a valve.	The solenoid isolation valves for the com-bustion chamber are designed in as a maintainable item. In the event of failure, the failed valve may be removed from the chamber assembly and replaced with a spare. Solenoid valve SV21 has a bac kup by way of manual vent valve MV5 which can be opened to provide a manual vent of chamber contents to the exhaust manifold.

		FOMA-06-02: Any one solenoid valve fails to close. (Stuck in open position)	2R	Loss of functionality on a primary control valve. Possible failure to isolate the other Sections of the FOMA from gases within the combustion chamber.	Failure to isolate a section of the FOMA from gases within the combustion chamber. Detection of this failure would essentially lead to system shutdown and Off-nominal procedures. (TBD) Undetected: Pre-combustion gases would be prevented from back-streaming to manifolds by check valves CV 1,2, and 10. Back-streaming into Exhaust Manifold would be prevented by SV24 and into the pump manifold by CV11.		Internal mechanical failure of solenoid valve. Large debris or contam-ination on valve seat.	PT 16,17, 28, and 29 will yield pressure measurements (pressure profile curve with time) which shows chamber pressure falls to an unexpected level after valves along the fill line are commanded to close. Will have to fault isolate to a valve.	The solenoid isolation valves for the com-bustion chamber are designed in as a maintainable item. In the event of failure, the failed valve may be removed from the chamber assembly and replaced with a spare.
		FOMA-06-03: Leakage	1R	SV 16,18,or 20: Release of pre-combustion gases. SV15,19, or 21: possible release of either pre-combustion or post-combustion gases.	Possible flammability hazard in the case of a leak of precombustion gases, or a toxicity hazard when post-combustion gases (burn products) are leaked.		Damage to valve seals or valve housing.	PT 16,17, 28, and 29 will yield pressure measurements (pressure profile curve with time) which shows chamber pressure falls to an unexpected level after valves along the fill line are commanded to close. Will have to fault isolate to a valve.	A Fault isolation procedure would be required to isolate which valve was leaking. System shutdown. The faulty solenoid valve would be removed and replaced with a spare.

MV5 : Manual Vent valve. (3 positioning / 3 way ball valve)	MV5 provides venting of the combustion chamber along a path which is an alternative to passing through SV21. It will allow the transfer of gases from the combustion chamber to the Exhaust Manifold. It also provides a path to vent gases from the chamber directly to the vent manifold (MV4 valve) in the event of an off-nominal procedure. Secondly, MV5 can be opened, we can turn on pumps 1 and 2 and open SV19, in order to run a gas circulation clean-up loop.	FOMA-06-03a:	TBD	TBD	TBD		TBD	TBD	TBD
Pressure Transducers	Monitor Pressure Readings inside the Combustion chamber. (PT 16,17, 28, and 29)	FOMA-06-04: Reads a pressure that is Lower than actual	1R	Provides incorrect data to computer and crew.	Could mislead the crew during an off-nominal condition leading to a failure to take corrective action when required.		Perform-ance drifts out of spec.	Failure of a transducer would provide readings that are contradicted by the other three transducers.	PT 16,17, 28, and 29 can be used to monitor the pressure profile in the combustion chamber. This provides a redundant function.
		FOMA-06-05: Reads a pressure that is Higher than actual.	2R	Provides incorrect data to computer and crew.	Could mislead the crew during a nominal condition leading to a corrective action which is not required.		Perform-ance drifts Out of spec.	Failure of a transducer would provide readings that are contradicted by the other three transducers.	PT 16,17, 28, and 29 can be used to monitor the pressure profile in the combustion chamber. This provides a redundant function
		FOMA-06-06: Fails to operate. No output.	1R	Provides NO data to computer and crew.	No data available on pressure profile in chamber. Loss of monitoring capability.		Open-circuit failure	Failure of a transducer would provide readings that are contradicted by the other three transducers	PT 16,17, 28, and 29 can be used to monitor the pressure profile in the combustion chamber. This provides a redundant function
		FOMA-06-07: Leakage	1R	Release of “pre” or post combustion gases into CIR.	Possible fire or toxic hazard.		Failure of seal or damage to Transducer	Other pressure transducers would indicate a drop in chamber	The fill operation would be shut down and the chamber would be vented. Off nominal

								pressure with solenoid valves closed.	procedure would be carried out to fault isolate to the transducer. The leak would be eliminated by a maintenance action.
Thermistors TM 1,2,3,4	Monitor temperature profile inside of the combustion chamber. [TM1,2, 3, and 4]	FOMA-06-08: Reads a temperature that is Lower than actual	1R	Provides incorrect data to computer and crew.	Could mislead the crew during an off-nominal condition leading to a failure to take corrective action when required.		TBD	Failure of a thermistor would provide readings that are contradicted by the other three thermistors.	TM 1, 2, 3 and 4 can be used to monitor the temperature profile in the combustion chamber. This provides a redundant function.
		FOMA-06-09: Reads a temperature that is Higher than actual.	2R	Provides incorrect data to computer and crew.	Could mislead the crew during a nominal condition leading to a corrective action which is not required.		TBD	Failure of a thermistor would provide readings that are contradicted by the other three thermistors.	TM 1, 2, 3 and 4 can be used to monitor the temperature profile in the combustion chamber. This provides a redundant function.
		FOMA-06-10: Fails to operate. No output.	1R	Provides NO data to computer and crew.	No data available on temperature profile in chamber. Loss of monitoring capability.		TBD	Failure of a thermistor would provide readings that are contradicted by the other three thermistors.	TM 1, 2, 3 and 4 can be used to monitor the temperature profile in the combustion chamber. This provides a redundant function.
		FOMA-06-11: Leakage	1R	Release of “pre” or post combustion gases into CIR.	Possible fire or toxic hazard.		TBD	Pressure transducers would indicate a drop in chamber pressure with solenoid valves closed.	The fill operation would be shutdown and the chamber would be vented. Off nominal procedure would be carried out to fault isolate to the transducer. The leak would be eliminated by a maintenance action.

Quick Disconnects	To provide connection of input gas lines to the combustion chamber. QD 11 , 12, and 13.	FOMA-06-12 : Will not engage	2R	Cannot provide input gas supply to the combustion chamber.	Loss of Combustion chamber function. Cannot perform experiments.		Disconnect coupler and nipple-spring failure.	Visual	Spring designed to avoid fatigue. Correct Installation procedures must be practiced.
		FOMA-06-13 : Difficult or unable to dis-engage	2R	Cannot perform maintenance action on a leaking QD.	Loss of Combustion chamber function. Cannot perform experiments.		Locking balls deform nipple. Caused by excessive vibration.	Visual	The QD design must be qualified for flight vibration levels.
		FOMA-06-14: Leakage in connected or disconnected position	1R	Leakage of pre-combustion gases or post-combustion gases into the CIR.	Loss of Combustion chamber function. Cannot perform experiments. Hazard- Release of flammable gases into the CIR.		Disconnect coupler & nipple- Failure of O-ring caused by damage, wear or aging	PT 16, 17, 28, and 29 would indicate a loss of pressure. In the combustion chamber.	Secondary metal-to-metal redundant seal. Disconnection or connection conducted with little or no pressure. Proper O-ring selection.
Mixture Fan	Provides optimum mixture for a particular composition of gases in the chamber. (noted as FAN)	FOMA-06-14: Fails to Operate.	3	Failure to obtain Optimum mixture.	None.		Electrical failure of Fan: short or open circuit.	Current readout on Fan circuit would show a over-current or open-circuit condition.	Fan would have to be qualified for flight and tested prior to deployment on orbit.

Filter	F 5, 6 and F10-	FOMA-06-15: Fails to stop contaminants	2R	Contaminants are passed on through the line.	GC: Contamination could skew analysis results of gas products.		Damage to Filter such as cracks or holes.	None.	None.
		FOMA-06-16: Fails to stop some contaminants.	3	Small amounts of contaminants are passed on through the line.	Contaminants are permitted to enter Exhaust manifold or Exhaust /vent Package.		Filter clogged with excessive Debris.	Data from other pressure transducers on the line would contradict transducer.	An off-nominal procedure is needed.
		FOMA-06-17: Clogged	2	Stops or greatly reduces gas flow to GC, Exhaust manifold, or vent manifold.	Cannot properly transfer gases to GC for analysis or cannot transfer gases to Exhaust Manifold from chamber.		Damage to Seals or housing of the filter.	Data from pressure transducers on the line such as PT 30, would contradict chamber transducer	Would shut down vent operation and safe the system. This off-nominal Procedure
		FOMA-06-18 Leakage	1R	Release of combustion or pre-combustion gases in to CIR.	Possible fire or toxic hazard.		Switch mechanism jammed by debris.	readings. However, there is no transducer on the line from MV5 to MV4. (TBD)	TBD.
Pressure Switches PS8 and PS9	PS8 and PS9 are intended to sense the drop in combustion chamber pressure following a burn and vent, thereby re-setting the timers controlling solenoid valves SV7 and SV8 in the Fuel/pre-mix Fuel manifold.	FOMA-06-19: Fails to Switch Mechanically.	2R	Timers control-ling SV7 and SV8 are not re-set.	Cannot re-open solenoid valves. Cannot flow fuel/pre-mixed fuel into chamber.		Electrical short or open	IOP and FCU will not receive a signal showing that SV7 and SV8 are open. State of timers will show that they are not re-set.	TBD
		FOMA-06-20: Fails to send Reset signal	2R	Cannot re-set timers control-ling SV 7 and 8.	Cannot re-open solenoid valves. Cannot flow fuel/pre-mixed fuel into chamber.		Holes, cracks, or loose mechanical fittings.	(same as above)	TBD
		FOMA-06-21: External leakage from mechanical connection	1R	Possible leakage of pre combust-ion or post combustion gases into CIR.	Possible fire or toxic hazard.		TBD	TBD	TBD

Combustion Chamber (includes optional ports, rear end cap, window assemblies, chamber window structural section, interface resource ring, and lid.)	The combustion chamber contains various mixtures of combustible gases and fuels and the actual combustion of these fuels. Various sensors provide monitoring data on temperature and pressure in the chamber or on gas input and output lines connecting to the combustion chamber.	FOMA-06-22: Burst/Rupture	1	Combustion chamber cracks open. Release of contained gases into CIR. Worst case: Chamber burst results in release of gases into CIR and projectiles with high energy. (example: Fragmentation of chamber windows) In worst case, Fire and toxicity hazard possible with damage to surrounding components.	Release of pre-combustion gases creates a Flammability hazard and release of post-combustion gases creates a toxicity hazard. Inability to contain combustion gases results in a termination of all experiments and a system shut-down. In the worst case scenario , escaped gases may lead to fire or toxicity threat (crew injury), and damage to other components of the CIR.		1. Improper design: Over-pressurization caused by loss of control on pressurization source or adiabatic combustion in chamber combines with insufficient margin of safety on structural strength. 2. selection of materials susceptible to stress-corrosion cracking, 3. Gaseous chemical composition/ Hardware material in-compatibility. 4. Un-detected damage from shock during ground processing or launch/assent vibration.	Inability of the chamber to hold a vacuum. Pressure transducers readings inside the chamber (PT 28 and PT 29) would indicate the condition.	Combustion Chamber will be designed with a structural factor of safety that will be xxMDP (based on yield) and xxMDP based on ultimate. The Chamber will be designed as a pressure vessel containing hazardous fluids and tested to comply with the intent of MIL-STD-1522A. (Approach A) as modified by NSTS 1700.7B, para. 208.4a. A hydrostatic proof test will be performed at 1.5 x chamber MDP. A separate test will be conducted without water to test the chamber windows. Materials will be selected on the basis of their compatibility with experiment fluids and cleaning agents in accordance with MSFC-HDBK-527/JSC 09604/MAPTIS database or approved MUA. There are at least 3 controls on pre-mix fuel flow to preclude conditions for adiabatic combustion: 1.) Pressure Regulator, 2.) IOP monitors Pressure transducers in pre-mix fuel manifold and chamber, 3.) fuel manifold has pressure switch to shut solenoid valve. And (4) – For experiments with non-continuous flow of fuel, igniters will be inhibited until GC identifies correct mixture.

Combustion chamber (includes optional ports, rear end cap, window assemblies, chamber window structural section, interface resource ring, and lid.)	The combustion chamber contains various mixtures of combustible gases and fuels and the actual combustion of these fuels. Various sensors provide monitoring data on temperature and pressure in the chamber or on gas input and output lines connecting to the combustion chamber.	FOMA-06-23: External Leakage	1R	Release of contained gases into CIR.	Release of pre-combustion gases creates a Flammability hazard and release of post-combustion gases creates a toxicity hazard. Inability to contain combustion gases results in a termination of all experiments and a system shut-down. In the worst case scenario , escaped gases may lead to fire or toxicity threat (crew injury), and damage to other components of the CIR.		Single seal Failure of Chamber windows, Chamber window glass crack occurs. (Critical flaws not caught at inspection) Crack growth from contact during installation of other CIR equipment. Seal failure from mech-anical fittings/ or loose fittings on resource ring. Leakage from defective optional ports.		A hydrostatic proof test of the chamber shell will be performed at 1.5 x MDP. A separate test will be conducted without water to test the chamber windows. Design verification will include Fracture Mechanics and NDI on the chamber to screen for critical initial flaw size. Seals will be tested on a ground unit for life and durability. Seals will be scheduled for change out based on testing and analysis with an adequate safety factor. A on-orbit Leak Integrity Check will be conducted before toxic test points. Functional testing of the chamber and associated diagnostics will be performed at the launch site and on-orbit to detect glass breakage.
Combustion Chamber Windows (8 total)	The 8 windows are symmetrically located around the outside of the chamber and provide optical access for the diagnostic packages.	FOMA-06-24a: Blemishing of Windows. FOMA-06-24b: Chamber windows cannot be removed.	2R TBD	Loss of / or distortion of optical data. TBD	Unable to carry out combustion exper-iments. TBD		The chemical effects of combustion gases en-hanced by the thermal energy of combustion and time. TBD	A distorted image would be indicative of a problem with the optics. A fault isolation procedure would rule out diagnostics and chamber windows would be checked. TBD	The windows have been designed to be removable from the inside of the chamber for service and change-out. TBD

Principle Investigator Unique Hardware (PIUH)		FOMA-06-xx: Failure of Thermocouple. (Reads temperature to be higher than actual, lower than actual, or gives no output) FOMA-06-xy: Failure of Radiometer. (Measures light intensity to be greater than actual, lower than actual, or gives no output) FOMA-06-xz: Igniter failure: Fails to ignite FOMA-06-xz: Igniter failure: Intermittent Failure to ignite FOMA-06-xz: Igniter failure: Inadvertent ignition	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Pump 3	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Pressure Switch PS5	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Check Valves CV 1,2,10,11	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Thermocouple TC2	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Pressure Transducer PT25	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Oxygen sensor O2S1	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

TABLE VII. FMEA WORKSHEET FOR THE FOMA Gas Chromatograph

*****MIL-STD-1522A test requirement modified as per NSTS 1700.7B paragraph 208.4.

Item	Schematic ID	Function	Failure mode and failure mode number	Crit	Local effect	System effect	Station/Crew Effects	Potential causes	Detection Method	Compensating Provision
Gas Chromatograph	GC	1. Verify combustion atmosphere created by either partial pressure or dynamic mixing methods. 2. Verify post-combustion atmosphere to insure concentrations are at acceptable vent levels.	FOMA-07-1 No output	3	Loss of function. No data output.	Loss of primary capability to verify that concentrations of gaseous mixtures (either before or after combustion) are within specified ranges for burning or venting. In the pre- ignition phase would result in a "Hold" on Ignition.	All TBD	Electrical open, short, or blockage of GC flow path tube by particulate contaminants.	No data signal from GC.	Critical blockage diameter in rela-tion to contam-inants is >10 microns. 10 micron filters F7 and F8 are locat-ed on GC input lines and on GC itself.
			FOMA-07-2 Erroneous measurement (Higher than actual)	2R	Incorrect data output to FCU.	See remarks above. In the case where GC reads higher than actual (erroneous measurement) it is possible that a decision could be made which places a hold on ignition. Venting may still be achieved but would require additional dilution for dumping.		Voltage or current drift out of spec.	Will detect peaks & values out of range.	**Note**: Normally, gas calibration standards are run initially. The standards pro-vide a measure of resolution and sensitivity and are certified with respect to purity. A trained GC op-erator will be alerted to the presence of negative peaks and values that fall outside of the expected range. MFC readings and delta pressure readings can still be used as a backup f or determining chamber composition.

			FOMA-07-3 Erroneous measurement (Lower than actual)	2R	Incorrect data output to FCU.	In the case where GC reads lower than actual (erroneous measure-ment) it is possible that a decision could be made which places a hold on ignition. Venting may still be achieved but would require additional dilution for dumping.		Voltage or current drift out of spec.	Will detect peaks & values out of range.	See note above.
			FOMA-07-4 Intermittent output	2R	Incomplete data	Loss of primary capability to verify that concentrations of gaseous mixtures (either before or after combustion) are within specified ranges for burning or venting. In the pre- ignition phase would result in a "Hold" on Ignition.		Loose circuit connections and/or loose internal components.	Will detect incom-plete data.	GC must be qualified to withstand launch vibe levels.
			FOMA-07-5 Leakage	2R	Release of Ar and He gases into CIR.	Loss of carrier gas required for diagnostics. Not a fire hazard and will not effect O2 content in the lab.		Failure of internal and/or External seals or joints.	Will detect no output or incomplete data from GC.	GC must be leak tested and qualified for flight.

Carrier gas bottles	GB4 Ar GB5 He	Allows the gas sample from the chamber to be transported through the columns of the GC for separation of individual components. The bottles are pressurized to 2000 psi.	FOMA-07-6 Burst	1	Loss of Function in GC columns.	High energy projectiles, and release of gases into CIR. Hazard.		Stress crack growth due to pressure or launch loads.	Visual & immed-iate.	Design would be for LBB: MIL-STD-1522A. Positive Margin for MBP. Hold on ignition or vent. FI to bottle. Go to Off-nominal Proc. Bottles should go through a contamination control process. Redundant filtering in design.
			FOMA-07-7 Leakage	2R	Loss of Function in GC columns.	Release of gases into CIR.		Crack growth in bottle wall. Creates leak.	PT19 or 20 may read low. TBD.	
			FOMA-07-8 Provides Contaminated Gas supply	2R	Loss of Function in GC columns. Cannot shut down gas flow from bottle.	Readings of GC will be distorted. Cannot properly measure gas compositions To verify that they are correct. loss of ability to shut down gas flow from source in an emergency.		Bottle did not comply with contamination control plan.		
Valves		To contain the carrier gas in the gas bottle	FOMA-07-9 Stuck Open	2R	Loss of GC column function: cannot achieve sample separation.	Results in failure of the GC to perform its function. Cannot proceed with ignition or venting.		Corrosion or contamination	PT 19 or PT 20 show pressure increase.	Valves should be tested and inspected. Qualified for flight.
			FOMA-07-10 Stuck Closed	2R	Release of Ar or He into GC package. Loss of working gas.	Release of Ar or He into CIR. Loss of carrier gas required for diagnostics. Not a fire hazard and will not effect O2 content in the lab.		Corrosion or contamination	PT 19 or PT 20 show no pressure increase.	Valves should be tested and inspected. Qualified for flight.
			FOMA-07-11 Leakage	TBD		Results in failure of the GC to perform its function. Cannot proceed with ignition or venting.		Corrosion or contamination Possible damage to valve.	PT 19 or PT 20 show reduced pressure increase.	Valves should be tested and inspected. Qualified for flight.
Quick Disconnects	QD09 & QD10	To provide connection of the carrier gas bottles to the CIR FOMA.	FOMA-07-12 : Will not engage	2R	Cannot provide carrier gas supply.	Loss of GC system function.	All TBD	Disconnect coupler and nipple-spring failure.	visual	Spring designed to avoid fatigue. Correct Installation procedures

										must be practiced.
			FOMA-07-13 : Difficult or unable to dis-engage	2 R	Cannot provide Re-placement of Carrier gas supply bottle.	Cannot proceed with GC function. Loss of function.		Locking balls deform nipple. Caused by excessive vibration.	Visual	The QD design must be qualified for flight vibration levels.
			FOMA-07-14: Leakage in connected or disconnected position	2R	Loss of carrier gas.	Loss of carrier gas required for diagnostics. Not a fire hazard and will not effect O2 content in the lab. Results in failure of the GC to perform its function.		Disconnect coupler & nipple- Failure of O-ring caused by damage, wear or aging.	PT 19 and 20 would read a pressure that is lower than expected.	Secondary metal-to-metal redundant seal. Disconnection or connection conducted with little or no pressure. Proper O-ring selection.
In-Line Filters	F7 and F8	To prevent particulates from entering the GC and the FOMA system during a Bottle change-out.	FOMA-07-15: Fails to stop contaminants FOMA-07-16:	2R	Worst case: Could cause GC to fail in no-output mode.	Worst case: Loss of ability to verify gaseous mixtures.		Blockage of GC Internal flow path.	No data signal from GC.	Critical blockage diameter in relation to contaminants is >10 microns. 10 micron filters F7 and F8 are located on GC input lines and on GC itself.
			Fails to stop some particles	3	None.	None.		Very small diameter, less than 10 microns.	None.	Must adhere to a Contamination control program.
			FOMA-07-17: Clogged	2R	Blockage of Ar or He flow. Loss of GC column function.	Worst case: Loss of ability to verify gaseous mixtures.		Contaminated gas supply or contaminated GC assembly.	Poor data or no data signal received from GC. Low pressure reading by PT 19 and 20.	TBD

			FOMA-07-18: External Leakage	2R	Loss of Ar or He flow rate.	Worst case: Loss of ability to verify gaseous mixtures.		Housing or seals On filter damaged. (in assembly- went undetected or by external environment)	Poor data or no data signal received from GC. Low pressure reading by PT 19 and 20.	TBD

Pressure Regulators	PR6 & PR 7	Maintain line pressure at 80 psig.	FOMA-07-19 Regulates pressure to a level that is higher than required.	2R	Pressure build-up in line.	Worst case: If Regulator & pressure relief valve failed, overpressure could result for GC.		Loss of setting /damage from launch vibe.	PT 19 and 20 will read high pressure.	Will initiate pressure relief. Pressure will be relieved at RV1,2,3, or 4.
			FOMA-07-20: Regulates pressure to a level that is Lower than required.	2R	Pressure in line is below what is Normal.	Worst case: GC sampling process stopped or GC gives inaccurate data. Worst Case: GC sampling process stopped or GC gives inaccurate data.		Loss of setting /damage from launch vibe.	PT 19 and 20 will read low pressure.	Would fault isolate to PR 6 or 7. Remove and replace. Re-start fill operation.
			FOMA-07-21: Leakage	2R	Pressure in line is below what is Normal.	Worst case: GC sampling process stopped.		Loss of setting /damage from launch vibe.	PT 19 and 20 will read low pressure.	Would fault isolate to PR 6 or 7. Remove and replace. Re-start fill operation.
Pressure Transducers	PT 19 and 20	Record the pressure input in line after the pressure regulators	FOMA-07-22: Reads a pressure that is higher than actual	2R	Worst case: Might cause IOP to command solenoid valves to close and shut off gas flow to GC.	Worst case: GC sampling process stopped or GC data is poor.		Loss of signal, Performance drifts out of spec.	**TBD**	**TBD**

			FOMA-07-23: Reads a pressure that is lower than actual	2R	Worst case: Pressure in line drops very low. Crew /computer Not informed.	Worst case: Loss of flow and GC sampling process stopped or GC gives inaccurate data.		Loss of signal, Performance drifts out of spec.	**TBD**	Pressure control back-up by PR6 & 7, and also RV1 – 4 to avoid over-pressurization .
			FOMA-07-24: Leakage	2R	Pressure in line is below what is normal /expected.			Damage to transducer / seal failure	**TBD**	**TBD**
Pressure Relief Valves	RV1,2,3, and 4.	RV1 and 3 set at 105 psia to prevent over-pressurization of GC. RV2 and RV4 set at 107 psia to act as redundant pressure relief valves.	FOMA-07-25: Valve fails to open.	2R	Redundant valve will be actuated.	Worst case: If both valves fail could damage GC and stop GC function.		Internal part failure of valve.	PT 19 or 20 would detect build up of pressure between regulator and solenoid valve.	Either SV25 or SV26 (whichever applies) would be commanded to close to cut off pressure input to GC.
			FOMA-07-26: Valve fails to close.	2R	Provides leakage path out from line.	Worst case: Loss of GC function.		Contamination or corrosion.	TBD	TBD
			FOMA-07-27: Valve leaks.	2R	Provides leakage path out from line.	Worst case: Loss of GC function.		Damage to valve or seal failure.	***See Comment (*) as Shown below.***	TBD

(*) Once the carrier gas line pressure is lost, the GC will not take a sampl e until the GC is reset. It is possible however, that the pressure relief valve could be leaking at a low rate of loss. This might still allow the carrier gas to be delivered to the GC at the correct pressure. Another possible scenario is that SV25 or SV26 could be closed and a leakage failure may occur. Until the line pressure drops below 80 psi (set regulator pressure) and either PT 19 or 20 read low pressure, the leak could go undetected.

* Pressure transducer internal to the column module in the Gas Chromatograph

Solenoid valves	SV25 & SV26	These valves open to allow carrier gas to flow to the GC. The valves are normally closed.	FOMA-07-28: Valves will not open.	2R	Cannot flow Ar or He to GC.	Ar or He carrier gas required for GC function is not provided. Loss of GC function.		Damage of internal parts.	PT * would measure low pressure output from GC.	TBD
			FOMA-07-29: Valves will not close.	2R	Cannot stop flow of carrier gas (either Ar or He).	May over-pressurize line in the event of pressure regulator failure. Possible damage of GC in worst case scenario.		Contamination or corrosion of the valve seat.	PT * would measure high pressure output from GC.	PT * monitors pressure output from GC, and pressure regulator is primary.
			FOMA-07-30: Leakage	2R	Loss of carrier gas supply needed for GC analysis.	Possible loss of GC system function.		Cracked seal or Other valve damage.	PT * would measure low pressure output from GC.	TBD
Calibration Gas Bottles	GB6	Allow the GC to be calibrated for qualitative and quantitative analysis. The bottles will be pressurized at 2000 psig.	FOMA-07-31: Burst	1	Rapid loss of gases needed for calibration of GC.	High energy projectiles, and release of gases into CIR. Hazard.		Stresses cause crack growth to Critical crack size. Induced by pressure or launch loads.	Visual, loss of pressure at PT22 if bottle bursts while connected to CIR.	Must design bottle to MIL-STD 1522A with positive margin on MBP.
			FOMA-07-32: Leakage	2R	Loss of gases needed for calibration of GC.	Unable to calibrate GC.		Crack propagates under wall surface just enough to create a hole for leakage.	PT 22 would measure a loss of pressure.	Must qualify bottle for flight vibration and effective internal pressure.
			FOMA-07-33: Provides contaminated supply.	2R	Contamin-ation flows into GC input gas line.	In the worst case scenario, contamination may enter GC and affect calibration adversely.		Bottle supply contaminated. Supplier did not follow a contamination control plan.	May not be able detect contamination prior to the GC.	Implement contamination control for the gas bottle.

Manual valve	MV8	To contain the calibration gas in the bottle	FOMA-07-34: Fails to open	2R	Cannot obtain calibration gas for the GC.	Cannot calibrate GC.		Corrosion on valve or damage.	PT 22 reads low pressure.	MV8 should be qualified for flight.
			FOMA-07-35: Fails to close	2R	Loss of calibration gas	Cannot calibrate GC.		Corrosion or contamination.	PT22 reading indicates valve open.	
			FOMA-07-36: Leakage	2R	Loss of calibration gas	Cannot calibrate GC.		Seal failure or damage to housing.	PT22 reads lower pressure than expected.	
Quick disconnect	QD8	Provides connection of calibration gas bottle to FOMA.	FOMA-07-37: Will not engage	2R	Cannot obtain calibration gas for the GC.	Cannot calibrate GC.		Disconnect coupler and nipple-spring failure.	Visual	Spring designed to avoid fatigue. Correct Installation procedures must <u>be practiced.</u>
			FOMA-07-38: Leakage in connected or disconnected position	2R	Loss of calibration gas	Cannot calibrate GC.		Disconnect coupler & nipple- Failure of O-ring caused by damage, wear or aging.	PT 22 would read a pressure that is lower than expected.	Secondary metal-to-metal redundant seal. Disconnection or connection conducted with little or no pressure. Proper O-ring selection.
			FOMA-07-39: Difficult or unable to dis-Engage.	2R	Cannot connect new gas bottle for re-calibration	Cannot calibrate GC.		Locking balls deform nipple. Caused by excessive vibration.	Visual	The QD design must be qualified for flight vibration levels.

Pressure Transducer	PT 22	Monitor the calibration gas pressure input to GC.	FOMA-07-40: No output	2R	Loss of pressure data "after" QD8 and "before" PR5.	Computer/crew would rely on reading now from PT 23 after pressure regulator.		Internal open-circuit or short. Internal mechanical failure.	Reading from PT 23 on pressure profile but no reading from PT 22.	TBD
			FOMA-07-41: Reads pressure higher than actual	2R	Erroneous data on line pressure.	In worst case scenario: May cause a pre-mature shut off of gas flow out of bottle.		Performance of Transducer drifts over time and out-of-spec.	Readings from PT 22 would not yield correct pressure.	**Might require a third transducer to determine a transducer malfunction on the GC calibration gas line.**
			FOMA-07-42: Reads pressure that is lower than actual	2R	Erroneous data on line pressure.	Failure could cause a pre-mature change out of the cal-ibration bottle. Could result in using up resources at a quick rate over what is anticipated.		Performance of Transducer drifts over time and out-of-spec.	Readings from PT 22 would not yield correct pressure profile.	**Might require a third transducer to determine a transducer malfunction on the GC calibration gas line.**
			FOMA-07-43: Leakage	2R	Loss of calibration gas.	Worst case: may not be able to calibrate GC.		Seal failure or damage to pressure transducer.	Readings from PT 23 will show pressure loss.	**TBD**
Solenoid valve	SV27	Flow control of calibration gas to the GC	FOMA-07-44: Valve fails to open	2R	Cannot flow Calibration gas to the GC.	Cannot calibrate GC.		Solenoid coil open-circuit. Most likely "coil burn-out".	PT 23 reads low pressure when valve is commanded open.	SV27 should be designed so that defective coil can be replaced.
			FOMA-07-45: Valve fails to close	2R	Cannot shut down calibration gas flow to GC	Worst case: If pressure regulator fails-to-regulate, GC could be damaged. Cannot control calibration process and have bottle re-loads.		Seat contaminated with debris, or corrosion in mechanical mechanism.	PT 23 will indicate a pressure that is higher than expected	Should be able to fault isolate to SV27, remove and replace valve.

			FOMA-07-46: Leakage	2R	Loss of calibration gas.	May not be able to calibrate GC due to loss of calibration gas.		Seal failure or damage to housing of valve.	PT 23 will indicate a pressure drop from what is expected	Shut down of gas calibration. Leak test, Fault isolate to leak. Remove and replace valve. CV4 would be removed and replaced.
Check valve	CV4	Check valve is intended as a protection: to prevent a sample of chamber gas from contaminating the calibration gas supply.	FOMA-07-47: Valve fails to allow flow-through of calibration gas when required.	2R	Cannot flow Calibration gas to the GC.	Cannot calibrate GC.		TBD	PT 23 reads low pressure after SV27 is commanded open. PT22 would read high and indicate gas was not flowing.	CV4 should be qualified for flight .
			FOMA-07-48: Valve fails to isolate cal-ibration gas bottle as intended.	2 R	Contamination of calibration gas supply bottle.	Subsequent calibrations of GC may be incorrect. Scientific data may be incorrect. Could adversely affect GC function. Decisions could be made to ignite Mixtures in the chamber that are incorrect.		TBD	PT 22 may show a unexpected pressure profile over time that indicates some back-streaming of sample gas from the chamnber. TBD.	CV4 should be qualified for flight .
			FOMA-07-49: Leakage	2 R	Loss of calibration gas.	May reduce the amount of calibration gas needed by the GC in order to successfully perform calibration.		Seal failure or damage to valve.	PT 23 may show a drop in pressure that is not expected.	
Pressure Regulator	PR5	To regulate sample gas delivery to the GC.	FOMA-07-50: Over-regulates Gas pressure input to GC. Reduces	2R	Low gas pressure and flow rate of sample gas into GC.	If sample mass is not large enough, GC analysis results may be inaccurate.		Loss of setting/ damage from launch vibe.	PT 23 reads a pressure that is lower than required.	*Will qualify PR5 pressure regulator design for flight and verify*

			pressure too low. FOMA-07-51: Fails to regulate Gas pressure input to GC. Input pressureis too high. FOMA-07-52: Leakage	 2R 1R	 High gas pressure and flow rate of sample gas into GC. Loss of sample gas from input line to GC.	 Unregulated or poorly regulated input pressure could damage GC. If sample mass is not large enough, GC analysis results may be inaccurate. Worst case: release of pre or post-ignition sample from combustion chamber which is flammable or toxic.		 Loss of setting/ damage from launch vibe. damage from launch vibe.	 PT 23 reads high pressure input to GC. PT 23 reads pressure input to GC decreasing.	*pressure regulator operates as part of the integrated system..* See above. See above.

***** Loss of calibration gas into the CIR if SV27 was open and calibration procedure was in process.

Pressure Transducer	PT 23	Measure the gas input pressure to the GC.	FOMA-07-53: Reads a pressure that is higher than actual FOMA-07-54: Reads a pressure that is lower than actual FOMA-07-55: Fails to function- No output FOMA-07-55A Leakage	2R 2R 2R 1R	Incorrect data about inlet pressure to GC. Incorrect data about inlet pressure to GC. **No** data about inlet pressure to GC. Loss of calibration or sample gas.	False alarm: may cause an action to close SV 27 when it is not necessary. Stops flow of sample gas. Stops GC analysis. False alarm: may cause an action to close SV 27 when it is not necessary. Stops flow of sample gas. Stops GC analysis. Off nominal procedureTBD : may cause an action to close SV 27 when it is not necessary. Stops flow of sample gas. Stops GC analysis. Worst case: Loss of gas sample from chamber-released into CIR. *****		Performance drift out of spec. Performance drift out of spec. Internal damage Seal failure or damage to transducer	TBD TBD No output signal from the transducer is provided to the IOP. TBD	Transducers will be tested as part of the integrated system and qualified for flight. Same Same same

In-line-Filter	F9	To prevent particulates with a diameter greater than 10 microns from entering the GC.	FOMA-07-56: Allows contaminants to enter GC.	2R	Possible blockage of GC flow path tube by particulate contaminants.	Worst case: loss of GC Functionality.		Calibration gas bottle is a contaminated source, or large particles from combustion chamber sample. [There would also have to be a hole in the filter or a filter installed with a micron rating greater than 10 microns.]	May be able to detect this type of failure by distorted GC readings. Worst case: May not be able to detect prior to loss of GC function.	Calibration gas bottle must be manufactured and filled under contamination control procedures. Gas mixtures burned in chamber must be planned to preclude particulates that exceed 10 micron diameter.
			FOMA-07-57: Clogged.	2R	Blockage of inlet flow path to GC.	Loss of GC function.		Untested GC system prior to Flight.	PT 22 and 23 show normal readings and GC provides no useful data.	Prior to flight GC package should be checked-out.
			FOMA-07-58: Leakage.	1R	Loss of gas sample.	Worst case: loss of GC function and release or pre-ignition or post-ignition sample gas from chamber.		Undetected damage to F9.	Pressure drop read by PT 23.	TBD
Pressure Transducer	PT 21	Measures the pressure in the gas sample line input to the GC	FOMA-07-59: Reads a pressure that is higher than actual	2R	Incorrect data about inlet pressure to GC.	False alarm: may cause an action to close SV 15 when it is not necessary. Stops flow of sample gas. Stops GC analysis.		Performance drift out of specification	TBD	TBD
			FOMA-07-60: Reads a pressure that is lower than actual	2R	Incorrect data about inlet pressure to GC.	False alarm: may cause an action to close SV 15 when it is not necessary. Stops flow of sample gas. Stops GC analysis.		Performance drift out of specification	TBD	TBD
			FOMA-07-61: Fails to operate. No reading	2R	**No** data about inlet pressure to GC.	Off nominal procedureTBD : may cause an action to close SV 15 when it is not necessary. Stops flow of sample gas. Stops GC analysis.		Internal damage	TBD	TBD

			FOMA-07-62: Leakage	1R	Leakage of sample gas from chamber into GC package & CIR	Could result in leakage of either pre-combustion mixture (fuel and oxygen) or Post-combustion products. (toxic)		Seal failure or damage to transducer /connection from launch vibe	TBD	TBD
Check Valve	CV3	Prevents calibration gas from entering the chamber sample line	FOMA-07-63: Valve fails to allow flow-through of chamber gas when required.	2 R	Cannot provide sample of chamber gas to GC.	Cannot perform analysis of chamber gas with GC.		TBD	PT 21 reads pressure build-up, and PT 23 reads low pressure. Previous operation shows all other components on Cal-gas line are OK.	TBD
			FOMA-07-64: Valve fails to isolate chamber Gas line from calibration gas.	3	Calibration gas may be able to back-flow along the chamber-sample gas line.	Chamber isolation valve SV 15 would be opened long enough to permit a sample of chamber gas to flow out but would then close. Some calibration gas would be trapped in this line. Might effect future readings by GC on chamber sample analysis.		TBD	TBD	TBD
			FOMA-07-65: Leakage	1R	Leakage of pre or post combustion gases and/or calibration gas.	Release of pre-combustion mixture and/or calibration gas into CIR.		Poor seal on valve or damage to exterior of valve.	TBD	Valve should be qualified for launch and flight conditions.

Check Valve	CV5	To prevent back-flow to the GC during a sample vent.	FOMA-07-66: Valve fails to allow flow-through of chamber gas when required.	2R	Cannot vent sample	Cannot continue to perform analysis of other chamber gas samples with GC.		TBD	PT 14 will not read the expected level of pressure.	TBD
			FOMA-07-67: Valve fails to isolate GC from sample gas being vented. (allows back-flow)	3	Sample gas back-flows into GC.	"erroneous measurement"			The first sample taken by the GC after the back-flow occurred would show an "erroneous measurement" and the trained operator analyzing this data would notice.	More samples would have to be taken until the line was cleared of the back-flow gas. The number of additional samples depends on the amount of back-flow gas that entered the GC. The trained operator would know when a "correct" sample was taken.
			FOMA-07-68: Leakage	1R	Leakage of pre-combustion gases and/or calibration gas.	Release of pre or post combustion mixture and/or calibration gas into CIR.		TBD	TBD	TBD

Check Valve	CV9	To prevent back-flow in the GC, sample line, or calibration line from the vent system during a purge.	FOMA-07-69: Valve fails to allow flow-through of gas when required.	2R	Cannot vent sample	Cannot continue to perform analysis of other chamber gas samples with GC.		TBD	PT 14 will not read the expected level of pressure.	TBD
			FOMA-07-70: Valve fails to isolate GC, sample and calibration line from sample gas being vented. (allows back-flow)	3	Sample gas back-flows into GC.	A GC sample could still be taken. Erroneous measurements would be observed until enough samples had been taken to clear the line of gas that should have been vented.		TBD	The first sample taken by the GC after the back-flow occurred would show an "erroneous measurement" and the trained operator analyzing this data would notice.	More samples would have to be taken until the line was cleared of the back-flow gas. The number of additional samples depends on the amount of back-flow gas that entered the GC. The trained operator would know when a "correct" sample was taken.
			FOMA-07-71: Leakage	1R	Leakage of pre or post combustion gases and/or calibration gas.	Release of pre-combustion mixture and/or calibration gas into CIR.		TBD	TBD	TBD

Pressure Transducer	PT 14	Monitoring of pressure in sample vent line	FOMA-07-72: No output	3	Loss of pressure data on vent line.	May result in a off-nominal venting procedure.		Loss of signal, Leaking, performance drifts out-of-spec. Open circuit.	No data from PT 14 flagged by IOP.	May be able to open SV22 and allow flow through to PT 30 to check out the pressure reading.
			FOMA-07-73: Reads a pressure that is higher than actual	3	Incorrect data on vent-line output pressure from GC.	May result in a off-nominal venting procedure.		Loss of signal, Leaking, performance drifts out-of-spec.	Data from PT14 is not as expected (make sense) when compared to readings from PT 30 and PT 23.	An off-nominal procedure can be developed to work-around the faulty transducer.
			FOMA-07-74: Reads a pressure that is lower than actual	3	Incorrect data on vent-line output pressure from GC.	May result in a off-nominal venting procedure.		Loss of signal, Leaking, performance drifts out-of-spec.	Data from PT14 is not as expected (make sense) when compared to readings from PT 30 and PT 23.	An off-nominal procedure can be developed to work-around the faulty transducer.
			FOMA-07-75: Leakage	1R	External Leakage	Leakage of pre or post combustion gases into CIR. May cause a halt in venting and a stop on experiments.		Defective seal or damage to component.	PT 30 reads lower pressure than what is expected.	May have to halt venting operation and remove and replace PT 14.

TABLE VIII. FMEA WORKSHEET FOR THE FOMA Exhaust Manifold

*****MIL-STD-1522A test requirement modified as per NSTS 1700.7B paragraph 208.4.

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Corrective Actions
FOMA-08: Exhaust Manifold									
Solenoid valve	SV1	Allows the flow of gas from the Static mixer to enter into the vent path.	FOMA-08-1: Valve fails to open	All TBD	All TBD unless otherwise indicated	All TBD unless otherwise indicated	All TBD unless otherwise indicated	All TBD unless otherwise indicated	All TBD unless otherwise indicated
			FOMA-08-2: Valve fails to close						
			FOMA-08-3: External Leakage						
			FOMA-08-04: Internal Leakage						
			FOMA-08-05: Intermittent operation						
Check Valve	CV12	To prevent back-flow of gas into the static mixer package	FOMA-08-06: Fails to open						
			FOMA-08-07:Fails to close						
			FOMA-08-08: Intermittent operation						
			FOMA-08-09: External Leakage						
			FOMA-08-10: Internal Leakage						
Solenoid valve	SV11	To prevent gas from entering the vent path during a filtration cycle.	FOMA-08-11: Fails to open						

			FOMA-08-12: Fails to close						
			FOMA-08-13: Intermittent operation						
			FOMA-08-14: External Leakage						
			FOMA-08-15: Internal Leakage						
Solenoid valve	SV 22	Allows a gas sample from the GC to enter either the adsorber cartridge or the vent path.	FOMA-08-16: Fails to open						
			FOMA-08-17: Fails to close						
			FOMA-08-18: Intermittent operation						
			FOMA-08-19: External Leakage						
			FOMA-08-20: Internal Leakage						
Solenoid Valve	SV24	When opened, allows chamber gas to enter adsorber cartridge. When adsorber cartridge is removed, SV24 must close to provide a closed system.	FOMA-08-21: Fails to open						
			FOMA-08-22: Fails to close						
			FOMA-08-23: Intermittent operation						
			FOMA-08-24: External Leakage						
			FOMA-08-25: Internal Leakage						

Pressure Transducer	PT 30	1. To measure the gas pressure entering the adsorber cartridge. 2. To provide one of the data points for calculating the differential pressure across the cartridge.	FOMA-08-26: Reads a pressure that is higher than actual						
			FOMA-08-27: Reads a pressure that is lower than actual						
			FOMA-08-28: Fails to operate: no data.						
			FOMA-08-29: External Leakage						1.Vicon seal pressed against manifold and sealing face of transducer is cracked, damaged, worn, or deteriorated.
Pressure Indicator	PI 5	To activate when the gas pressure in the line is greater than 30 psi. in order to indicate whether it is safe to install or uninstall the adsorber cartridge.	FOMA-08-30: Activates at a pressure above safe-pressure threshold						
			FOMA-08-31: Activates at a pressure below safe-pressure threshold						
			FOMA-08-32:Fails to activate						
			FOMA-08-33:Intermittent operation						

TABLE IX. FMEA WORKSHEET FOR THE FOMA Adsorber Cartridge

*****MIL-STD-1522A test requirement modified as per NSTS 1700.7B paragraph 208.4.

Item	Sche-matic ID	Function	Failure Mode and Failure Mode Number	Crit.	Local Effect	System Effect	Station/Crew Effects	Detection Method/ Time-to-Effect=TE /Time-to-Detect=TD	1.Potential Causes and 2. Corrective Actions
FOMA-09: Adsorber Cartridge									
Manual Valve	MV9	To provide isolation for the cartridge	FOMA-09-01:Fails to open	All TBD unless otherwise indicated	All TBD unless otherwise indicated	All TBD unless otherwise indicated	All TBD unless otherwise indicated	All TBD unless otherwise indicated	All TBD unless otherwise indicated
			FOMA-09-02: Fails to close						
			FOMA-09-03: Intermittent operation						
			FOMA-09-04: Internal Leakage						
			FOMA-09-05: External Leakage						
Manual Valve	MV10	To provide isolation for the cartridge	FOMA-09-06:Fails to open						
			FOMA-09-07: Fails to close						
			FOMA-09-08: Intermittent operation						
			FOMA-09-09: Internal Leakage						
			FOMA-09-10: External Leakage						
Quick Disconnect	QD6	To provide transfer of gas from Adsorber cartridge to vent manifold	FOMA-09-11: Fails to allow a safe/correct and complete connection						
			FOMA-09-12: Fails to allow disconnection						
			FOMA-09-13: External Leakage						

			FOMA-09-14: Inhibits flow						
Quick Disconnect	QD7	To provide transfer of gas from Exhaust manifold to Adsorber cartridge	FOMA-09-15: Fails to allow a safe/correct and complete connection						
			FOMA-09-16: Fails to allow disconnection						
			FOMA-09-17: External Leakage						
			FOMA-09-18: Inhibits flow						
Adsorber Cartridge	Item name	Remove undesirable gases from the post-combustion mixture to acceptable vent-ing concentrations	TBD						
FOMA-13: Pump assembly and misc. devices									
Pump 1 and 2	Item name	To pump chamber gas through the adsorber cartridge	TBD						
Thermistors	TM 8,9	To monitor the pump motor temperatures.	TBD						
Oxygen Sensor	O2S1	To detect the concentration of oxygen exiting the chamber to be vented.	TBD						
Pressure Transducer	PT13	1.To measure the gas pressure exiting the adsorber cartridge 2. Provides 2nd. data point for the differential pressure across the cartridge.	TBD						

In Line Orifice	ORI	To reduce pressure to 40 psi for gas exiting along the emergency vent path when the ISS vent valve is open.	TBD						
Three-way manual ball valve	MV4	Enables flow of gas from the EVP vent line or the emergency vent line with the overboard vacuum vent lines in the CIR.	TBD						
Quick Disconnect	QD5	Provides a connection to the overboard vacuum vent lines and allows transfer of gas from the FOMA to the overboard vacuum vent lines.	TBD						
Filter	F7	To protect SV19 and the combustion chamber from particulate matter existing in the pumps	TBD						

9.0 CRITICAL ITEMS LIST

TABLE X. Critical items List

Item Name	Reference to FMEA Worksheets	Failure Modes by Number	Is There Failure detection	Provisions For Design/Test/Operation/Maintenance or Corrective Action
Gas Bottle GB2	TBD	FOMA-01-1	Immediate effects such as pressure loss in pre-mix gas fill line registered by pressure transducers and PI2 pressure indicator, and/or visual indication that gas bottle has cracked open.	1.Structural failure. Stress cracking due to launch environment, or thermal effects. 2. Would shutdown the system, remove any possible ignition sources, remove damaged bottle, ventilate area, Inspect for damage, Conduct maintenance.
GB3 Gas Bottle	TBD	FOMA-03-1	Visual, immediate effects.	GB2 designed for: LBB, tested as per MIL-STD 1522A* with positive margin of safety on burst/MDP and FS requirements. Proof tests.
PR3 Pressure Regulator	TBD	FOMA-03- 35	PT 26 would indicate pressure.	Design of pressure regulator is maintainable: If regulator is leaking due to seal failure, entire regulator can be removed and replaced. Bottle size and amount of gas are selected to avoid flammability/toxic substance concerns.
GB-1 Oxygen Supply Bottle	TBD	FOMA-04-1	Visual and immediate effect.	Design GB1 as LBB. Qualify per MIL-STD-1522A. *
Combustion Chamber (includes optional ports, rear end cap, window assemblies, chamber window structural section, interface resource ring, and lid.)	TBD	FOMA-06-22:	Inability of the chamber to hold a vacuum. Pressure transducers readings inside the chamber (PT 28 and PT 29) would indicate the condition.	Combustion Chamber will be designed with a structural factor of safety that will be xxMDP (based on yield) and xxMDP based on ultimate. The Chamber will be designed as a pressure vessel containing hazardous fluids and tested to comply with the intent of MIL-STD-1522A. (Approach A) as modified by NSTS 1700.7B, para. 208.4a. A hydrostatic proof test will be performed at 1.5 x chamber MDP. A separate test will be conducted without water to test the chamber windows. Materials will be selected on the basis of their compatibility with experiment fluids and cleaning agents in accordance with MSFC-HDBK-527/JSC 09604/MAPTIS data base or approved MUA. There are at least 3 controls on pre-mix fuel flow to preclude conditions for adiabatic combustion: 1.) Pressure Regulator, 2.)IOP monitors Pressure transducers in pre-mix fuel manifold and chamber, 3.) fuel manifold has pressure switch to shut solenoid valve. And (4) – For experiments with non-continuous flow of fuel , igniters will be inhibited until GC identifies correct mixture.

Carrier gas bottles	TBD	FOMA-07-6	Visual & immediate.	Design would be for LBB: MIL-STD-1522A. Positive Margin for MBP. Hold on ignition or vent. FI to bottle. Go to Off-nominal Proc. Bottles should go through a contamination control process.Redundant filtering in design.
Calibration Gas Bottles	TBD	FOMA-07-31	Visual, loss of pressure at PT22 if bottle bursts while connected to CIR.	Must design bottle to MIL-STD 1522A with positive margin on MBP.

10.0 CONCLUSIONS AND RECOMENDATIONS

TBD

11.0 NOTES

TBD

APPENDEX A. ACRONYMS AND ABBREVIATIONS

A.1 SCOPE

This appendix lists the acronyms and abbreviations used in this document.

A.2 LIST OF ACRONYMS AND ABBREVIATIONS

CAN	Controller Area Network
CIL	Critical Items List
CIR	Combustion Integrated Rack
FCF	Fluids and Combustion Facility
FIR	Fluids Integrated Rack
FMEA	Failure Modes and Effects Analysis
IOP	Input / Output Processor
IPP	Image Processor Package
IPSU	Image Processing and Storage Unit
ISS	International Space Station
JSC	Johnson Space Center
MM/OD	Micrometeor / Orbital Debris
SAR	Shared Accommodations Rack
SDL	Serial Data Link

APPENDEX B. DEFINITIONS

Failure Mode Number – A number on the FMEA worksheet which identifies a particular hardware item, a specific failure mode, and the corresponding block on the schematic.

Item – A part, component, combination of parts, usually self-contained.

Function – An action or process performed by a sub-system or component by design, which usually involves the transfer of energy and may include the transfer of information. [Note: an alternative definition may apply to passive components of a system such as structure whose "function" is load bearing capability. Welds, brazings, and epoxy have a function which is to provide adhesion of parts when subjected to forces. "Function" applies to fuels or oxygen in that their function is to transform energy from stored (potential) chemical energy to thermal energy.]

Failure – The inability of a system, subsystem, component or part to perform its required function within specified limits, under specified conditions for a specified duration.

Failure Mode – A description of the manner in which an item can fail.

Criticality – The assigned category of a failure mode based upon the severity of its worst case effect which indicates if the failure mode is a single point failure or occurs from the failure of redundant devices.

Local Effect – The consequences a failure mode has on the operation, function, or status of other items (within the payload system) which interface with the specific item being analyzed.

System Effect – The consequence(s) a failure mode has on the operation , function, or status of the overall system.

Hazard – Existing or potential condition that can result in, or contribute to, the injury or loss of personnel or loss of an entire facility.

Single Point Failure – A single item of hardware, the failure of which will lead directly to a hazard, reduce ability to conduct science or result in a mission critical worst case failure effect.